4th CONFERENCE ON TOXIC SUBSTANCES

Montreal, April 4-5, 1990

4e COLLOQUE SUR LES SUBSTANCES TOXIQUES

Montréal, 4 et 5 avril 1990

PROCEEDINGS

COMPTE RENDU

Air & Waste Management Association
Association pour la Prévention de la Contamination de l'Air et de Sol
Environment Canada
Conservation and Protection
Environnement Canada
Conservation et Protection
Gouvernement du Québec
Ministère de l'Environnement
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PROCEEDINGS

4th Conference on
Toxic Substances

April 4-5, 1990
Queen Elizabeth Hotel
Montreal, Québec

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4e Colloque sur les
substances toxiques

4 et 5 avril 1990
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Montréal (Québec)

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Le comité organisateur du 4e Colloque sur les substances toxiques aimerait souligner la qualité du travail des conférenciers pour la préparation de leur présentation ainsi que de celui des modérateurs pour leur précieux apport au bon déroulement de la conférence.

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THE CONTAMINATION OF SEAS

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ABSTRACT

Basically, five classes of toxic substances enter the seas as toxic contaminants: (1) petroleum hydrocarbons; (2) polycyclic aromatic hydrocarbons; (3) halogenated hydrocarbons; (4) metals; and (5) radionuclides. All are present in nature to some degree, but human activity has added greatly to their amounts and variety in the oceans. Although radionuclides were initially of greatest concern, the synthetic organochlorine compounds have probably posed the most serious ecological and human health hazards. Long-range atmospheric transport of these substances has contributed to their presence in remote areas, such as the Arctic, where food of native people is being contaminated. Point source releases of contaminants to the seas are being partly controlled by international treaties and regulations under national legislation. Non-point sources of contaminants in urban and agricultural runoff and in the atmosphere are more difficult to control. Contamination by toxic substances, such as dioxins and furans, inadvertently produced and released into coastal waters by industry, is a cause for concern about the threat to the health of seafood consumers in areas like coastal British Columbia. Fisheries closures in the affected areas have been the only available short-term solution until corrective action can be taken by the pulp and paper industry to stem these releases, and there is assurance that the contaminants are no longer being released by the sediments to become available for uptake by edible marine organisms. Contamination of the Arctic, which is bordered by seven different nations and receives most of its contaminants by long-range atmospheric transport, can only be controlled by international treaty, with action taken to control atmospheric emissions by individual nations.

INTRODUCTION

A host of substances contributed by humanity has contaminated the seas over the course of human history. Many of these materials are toxic. Others are not toxic but are persistent, such as plastic, and damage the ecosystem and marine organisms in a variety of ways, including entanglement. Because this Conference is devoted to toxic substances, the persistent, non-toxic, solid materials will not be considered here.

In the case of some marine constituents, human input in the oceans merely adds to substances already there through the geological weathering and erosion processes over millions of years on land. This applies to the metals and radioactive elements, which are all present in seawater naturally in minute concentrations. It applies also to some organic constituents that are produced by marine plants and animals, or in the case of petroleum hydrocarbons, they may enter the seas from natural seeps.

Attention in this paper will be focussed on synthetic, man-made, toxic substances that enter the sea in one way or another. These are mainly the halogenated hydrocarbons, most of which are persistent and many of which are highly toxic. Few are deliberately discharged into the sea, but because of the nature of their uses, i.e., as pesticides in agriculture and forestry, they readily

reach the aquatic and atmospheric environments through which they are transferred to the oceans. Some are unintentionally produced, e.g., dioxins and furans, through combinations of such residual chemicals as chlorine and phenolic organic compounds in effluents from pulp and paper mills. Other toxic organic compounds, such as the polycyclic aromatic hydrocarbons, also have carcinogenic properties, and these are of concern not only from the human health point of view, but also because their presence in sediments has an adverse effect on bottom fish.

Radioactive substances are toxic and have the added harmful effect of ionizing radiation that damages plant and animal tissues. Their introduction into the environment causes public alarm even though they are naturally present in all materials, including seawater, and radiation from natural sources may be comparatively high. This public perception is in part responsible for the strong opposition in some quarters to nuclear reactors as commercial power sources. Nuclear reactor accidents such as the one at Chernobyl, USSR, in April 1986, do not help to allay public concern about radioactive releases into the environment from nuclear reactors. To keep the matter in perspective globally, the point is discussed in the section on radionuclides that ground-surface nuclear weapons tests from 1945 to 1963 were the major source of radioactivity to the world oceans. This source has significantly declined since the Partial Test Ban Treaty of 1963. The problem of marine radioactivity has substantially diminished in the last quarter century.

A serious problem of contamination of the seas has arisen from long-range atmospheric transport of contaminants from industrialized areas of the world to remote regions, such as the Arctic. Because the traditional diet of the Inuit depends largely on such marine mammals as seals, narwhals and beluga whales, the health of these native people is endangered by high concentrations of such toxic substances as polychlorinated biphenyls, toxaphene and DDT in the blubber of these animals. It is clear that such issues cannot be resolved by one nation alone but will require the cooperative efforts of many nations which may be responsible for the atmospheric emissions that are transported to distant places.

Although generally Canadian contamination problems are discussed in this paper, an attempt is made to consider them in a global context, and in that regard, some problems of other parts of the world oceans are noted.

TOXIC CONTAMINANTS

There is a wide range of toxic chemicals that enter the seas. Worldwide, over 4 million chemicals are presently registered with about 70,000 in commercial use (Somers, 1982). Environment Canada is now developing a priority list of about 44 chemicals which present concerns. A review was conducted of these substances in a Priority Substances Science Forum held at the Canada Centre for Inland Waters, Burlington, Ont., 22-23 February 1989 (Waterston, 1989). Most of these substances, among others, can be grouped into five classes, according to their biological effects, persistence and general behaviour in the marine environment: (1) petroleum hydrocarbons; (2) polycyclic aromatic hydrocarbons; (3) halogenated hydrocarbons; (4) metals; and (5) radionuclides. Some compounds may be acutely toxic but are highly unstable and short-lived in the marine environment. While such substances may pose a lethal condition for marine organisms for a brief period, they are unlikely to be bioaccumulated and are not expected to present a long-term hazard to either the exposed organisms or to their predators, including man.

1. Petroleum Hydrocarbons

Petroleum hydrocarbons range from crude oil, thro gh various refined products such as gasoline and kerosene to heavy oils, e g., Bunker C, and residues of tar. They enter the seas from a variety of source — exploration for and exploitation of oil in the seabed, transport, runoff, m nicipal wastewaters and the atmosphere. The latest best estimate is that about 3.2 million tons of oil enter the sea each year, with a probable range of 1.7-8.8 million tons (NAS, 1985). The most dramatic inputs are from major oil s ills, such as the 875,000-litre spill of Bunker C from the barge *Nestucca* on he southwest coast of Washington in December 1988 (Waldichuk, 1989), and he 41-million litre spill of crude oil from the *Exxon Valdez* in Prince William Sound, Alaska, on 24 March 1989 (Hodgson, 1990).

Petroleum hydrocarbons in the form of crude oil are ot acutely toxic in themselves, but they do contain highly-volatile, toxic fractions and the polycyclic aromatic hydrocarbons, some of which are carcino genic. Oil pollution on beaches can be highly destructive to oyster beds a id other shellfish resources, as well as to fish-spawning grounds. The greates biological impact, however, is on birds, sea otters and other animals that depen on feathers or fur for insulation from the cold. Preening of feathers and groom ing of fur can lead to ingestion of oil and subsequent liver damage in both b rds and mammals. Because oil floats, it moves with surface currents and strong ly responds to the action of winds. If it drifts onto shore through the acti n of wind-driven currents, it inflicts its greatest damage in the intertidal zo e, where it wreaks havoc among shoreline organisms as well as destroying b each amenities. In coastal areas highly dependent on tourism, the econom ic impact can be enormous. Cleanup costs alone can be particularly high. It has been estimated that the cost to Exxon for the *Exxon Valdez* oil spill in Pr nce William Sound exceeded $1 billion (Hodgson, 1990). Nearly 2,000 km of oil-soaked shoreline had to be cleaned. In low-energy beach areas, where the ction of tides and waves is ineffective in cleaning the oil off beach material, oil residues may remain for a decade or more.

Depending on the nature of the oil spilled, the impact of contamination may last several years or only a season or two. The lighter fractions of oil are generally the more toxic, and spills of such materials, if they drift onto shore, can be devastating to intertidal organisms. A spill of 9.54 million litres of diesel fuel from the *Tampico Maru* off the coast of Baja California, Mexico, in March 1957 led to heavy mortality of clams, mussels, sea urchins, starfish and other intertidal organisms (North *et al.*, 1965). The heavy mortality of invertebrates subsequently led to a great profusion of nearshore seaweeds, apparently because the grazers, particularly the sea urchins, had been destroyed (Mitchell *et al.*, 1970). Thus the intertidal ecosystem was at least temporarily altered. It was believed that the impact of the *Tampico Maru* diesel fuel could be identified for at least a decade (NAS, 1985).

Crude oil spills have also had lasting effects, but the initial acute toxicity of the oil to marine organisms has generally not been as great. The large 137 million-litre spill of the *Torrey Canyon* in the English Channel in 1967 had a severe impact on marine organisms along the southern coast of England. But the effect of dispersants used to combat that oil spill was probably worse than the effect of the oil itself would have been (Smith, 1968). The huge *Amoco Cadiz* oil spill off the coast of Britanny, France, in 1978 had a devastating effect on oysters and other shellfish in this coastal area,and the impact did not disappear for several years. Although fisheries were affected, following the *Exxon Valdez* oil spill in Prince William Sound, through closures of both salmon and herring fisheries to prevent oil-contaminated products from

reaching the markets, the worst biological effects arose from destruction of tens of thousands of sea birds and over a thousand sea otters in the area, whose plumage and fur became seriously soiled by the oil (Waldichuk, 1990).

On the average, the amount of oil entering the sea annually is declining, because of better control at oil-transferring shore facilities, on tankers and in refineries. Globally, less oil is being transported by sea now than in the mid-1970s, with an estimated 25% decrease from 1977 to 1985, an annual reduction of 43 million tons. The trends in concentrations of petroleum hydrocarbons in the Gulf of St. Lawrence from 1971 to 1979 (Figure 1) (Levy, 1984; Environment Canada, 1986) may not fully reflect global trends, but they do show a decline in one coastal area that has a considerable amount of tanker traffic and a modest number of petroleum refineries and petroleum-handling shore facilities.

2. Polycyclic Aromatic Hydrocarbons

A certain fraction of crude oil consists of the polycyclic aromatic hydrocarbons (PAHs). These compounds are not only toxic, but some components, e.g., benzo (a) pyrene, are also quite carcinogenic. Besides originating in petroleum hydrocarbons, PAHs may stem from incineration, creosoted pilings, tar that is produced in steel-mill coking ovens, e.g., tar ponds in Sydney Harbour, N.S., and from aluminum smelters. They may enter the sea from direct discharges, urban runoff, leaching from creosoted timber and tar deposits or by way of the atmosphere. They are not particularly soluble in seawater and usually become fixed in the sediments. High concentrations of PAHs can be expected in harbours containing heavy industry and much maritime traffic.

The steel industry in Sydney, N.S., produced coke from coal for the high temperature required in its steel production. Tar from the coke ovens entered Muggah Creek and formed tar ponds, which are now scheduled for removal and destruction by incineration. In the South Arm of Sydney Harbour, the sediments exhibit PAH concentrations exceeding 1000 $mg \cdot kg^{-1}$, which are inversely proportional to the distance of the sampling sites from Muggah Creek (Matheson *et al.*, 1983). Presence of high concentrations of PAHs in lobsters in Sydney Harbour led to closure of the lobster fishery there in 1982. Concentrations of PAHs in the edible tomalley (digestive gland) of lobsters reached 78 ppm, wet weight, compared to an estimated background level of 3 ppm in coastal lobsters well removed from the tar ponds (Eaton *et al.*, 1984). The lobster fishery in Sydney Harbour will probably remain closed until the tar ponds have been removed.

Studies in Burrard Inlet, British Columbia (Goyette and Boyd, 1989), indicated a high incidence of skin tumours and liver lesions in bottom fish associated with elevated levels of PAHs in the sediments. Although Burrard Inlet is closed to fishing because of industrial pollution, the high concentrations of PAHs in the sediments pose a problem for disposal of dredged material from the inlet. The Regional Ocean Dumping Advisory Committee for the Pacific and Yukon Region has developed interim guidelines for ocean disposal of dredge material contaminated by PAHs. The screening limit for total PAHs in sediments to be dredged for ocean disposal is 2.5 $\mu g.g^{-1}$, dry weight. The rejection levels, which would prohibit ocean disposal if the concentrations exceeded these, are 6.0 $\mu g.g^{-1}$, dry weight, for low molecular weight PAHs and 50.0 $\mu g.g^{-1}$, dry weight, for high molecular weight PAHs. Sediments that are below the screening limit for total PAHs may be dumped at sea, provided they meet the other regional guidelines and regulations under Part VI of the Canadian Environmental Protection Act. Sediments that exceed the screening limit, but are below the rejection levels for both low molecular weight and high molecular weight PAHs,

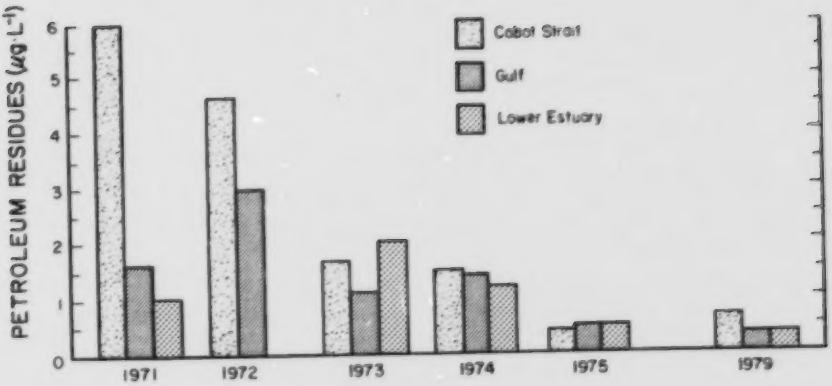

FIGURE 1. TRENDS IN CONCENTRATIONS OF PETROLEUM HYDROCARBONS IN THE GULF OF ST. LAWRENCE AND CONTIGUOUS WATERS FROM 1971 TO 1979. (ADAPTED FROM LEVY, 1984, *IN* ENVIRONMENT CANADA, 1986)

must be subjected to bioassays with benthic amphipods and with oyster larvae or echinoderm larvae, if the proponent wishes to pursue the ocean disposal option. Some applications are rejected on the basis of results of bioassays with oyster larvae or echinoderm larvae, which may exhibit deformities due to exposure to PAHs, even though the sediments may pass the benthic amphipod bioassays.

PAHs are not normally directly disposed of in the sea. They reach coastal waters largely through runoff and by way of the atmosphere. Control of input of contaminants to the oceans via these pathways is extremely difficult, because they do not constitute point sources. If major sources that contribute to PAHs in runoff and the atmosphere can be identified, however, then steps can be taken to stem the flow of PAHs through these media.

3. Halogenated Hydrocarbons

In this class of substances are many of the organochlorine compounds used as pesticides. It also includes the polychlorinated biphenyls (PCBs), industrial chemicals used in electrical transformers and capacitors and in plasticizers, printing inks and other industrial applications. These compounds are generally all very stable and resist breakdown by bacterial action. In the case of DDT, its degradation products, such as DDE, are as ecologically damaging as the parent compound.

The traditional organochlorine pesticides, such as DDT, dieldrin, aldrin, endrin and hexachlorocyclohexane, are declining in the marine environment of the northern hemisphere. This trend is due to restrictions on their uses imposed in the 1970s by regulations under national legislation in many countries. For example, because of the observed adverse effects on fish from spraying forests in New Brunswick with DDT (Kerswill and Edwards, 1967), there was a change to non-organochlorine insecticides in New Brunswick's operational forest spray program after 1966 (Figure 2) (Eaton *et al.*, 1986). A shift has occurred, however, in the last two decades from their application in agriculture and forestry at mid latitudes in the northern hemisphere to agriculture and mosquito eradication for malaria control in the tropics and southern hemisphere (Goldberg, 1975). The changes in DDT concentrations in seawater at various locations of the Pacific Ocean, from 1975-1977, through 1978-1981 to 1982-1985, are shown in Figure 3 (Tatsukawa, unpublished data).

PCBs were banned for uses in new devices in most developed countries and in some developing countries during the 1970s. They continued to be used, however, in existing electrical transformers and capacitors. Old transformers and capacitors, which were taken out of use,were often stored with their contents of PCBs, and some of them eventually leaked. Hence, PCBs continued to enter the environment, albeit in smaller amounts. The decline in PCB residues in seawater of the Pacific and Indian Oceans, as observed by Japanese scientists, is shown in Figure 4 (Tatsukawa, unpublished data).

PCBs continue to be found in marine organisms, particularly mammals, however, in remote areas, such as the Canadian Arctic, well removed from industrial sources. The PCBs reach those areas mainly by long-range atmospheric transport. The Japanese point to co-planar PCBs, considered to be highly toxic, as being present in marine mammals at great distances from their sources, and obviously transported there by tropospheric winds (Tanabe *et al.*, 1989).

Low-molecular-weight halogentated hydrocarbons include the chlorofluorocarbons that have seen extensive use in refrigeration systems, aerosol propellants in hair sprays and pressurized paint sprays, and as gas for blowing styrofoam containers. Their uses have declined in the last decade because of controls imposed to stem the erosion they cause of the stratospheric

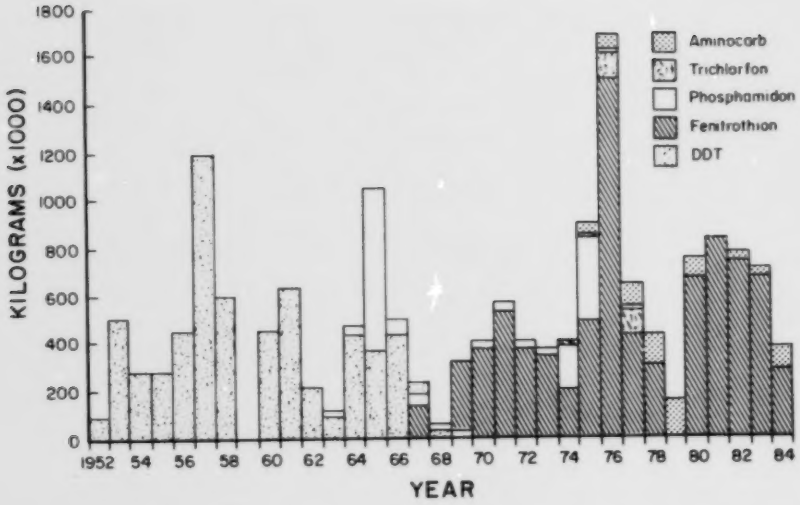

FIGURE 2. CHANGES IN THE USAGE OF CHEMICAL INSECTICIDES IN NEW BRUNSWICK'S OPERATIONAL FOREST SPRAY PROGRAM FROM 1952 TO 1984. (FROM EATON *ET AL.*, 1986)

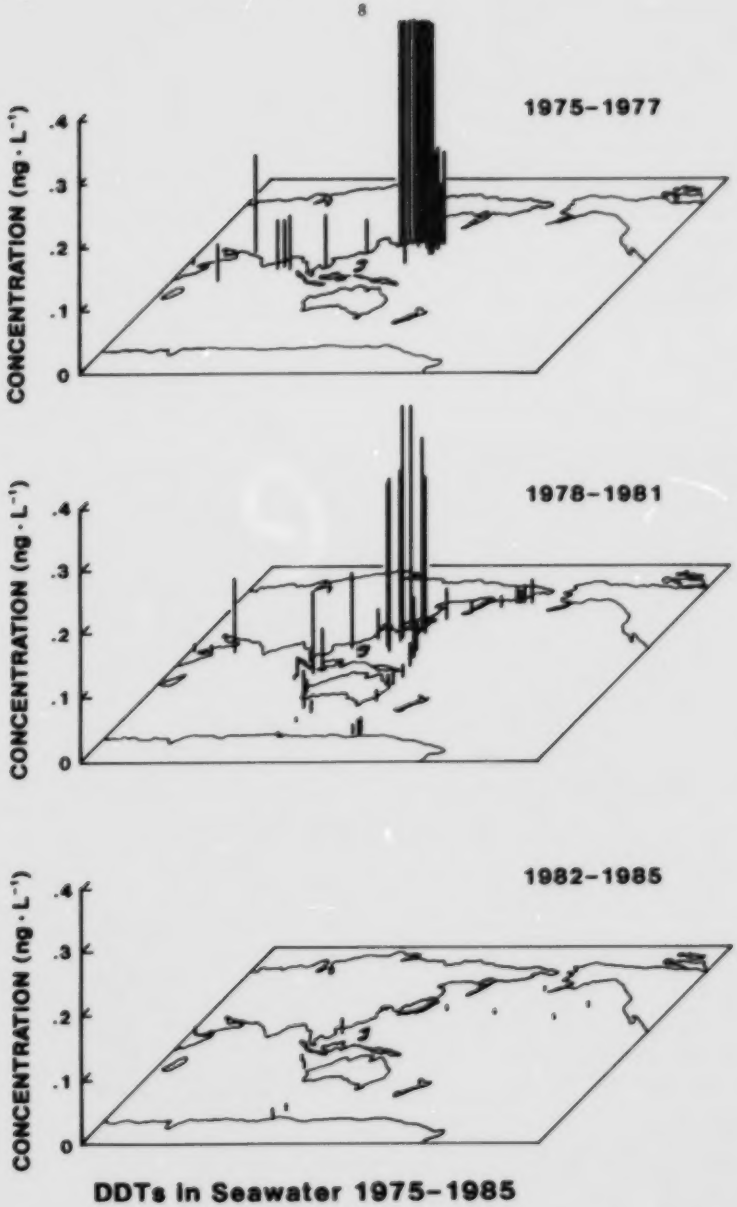

FIGURE 3. DECLINE OF DDTs IN SEAWATER OF THE PACIFIC AND INDIAN OCEANS FROM 1975 TO 1985. (FROM TATSUKAWA, UNPUBLISHED DATA)

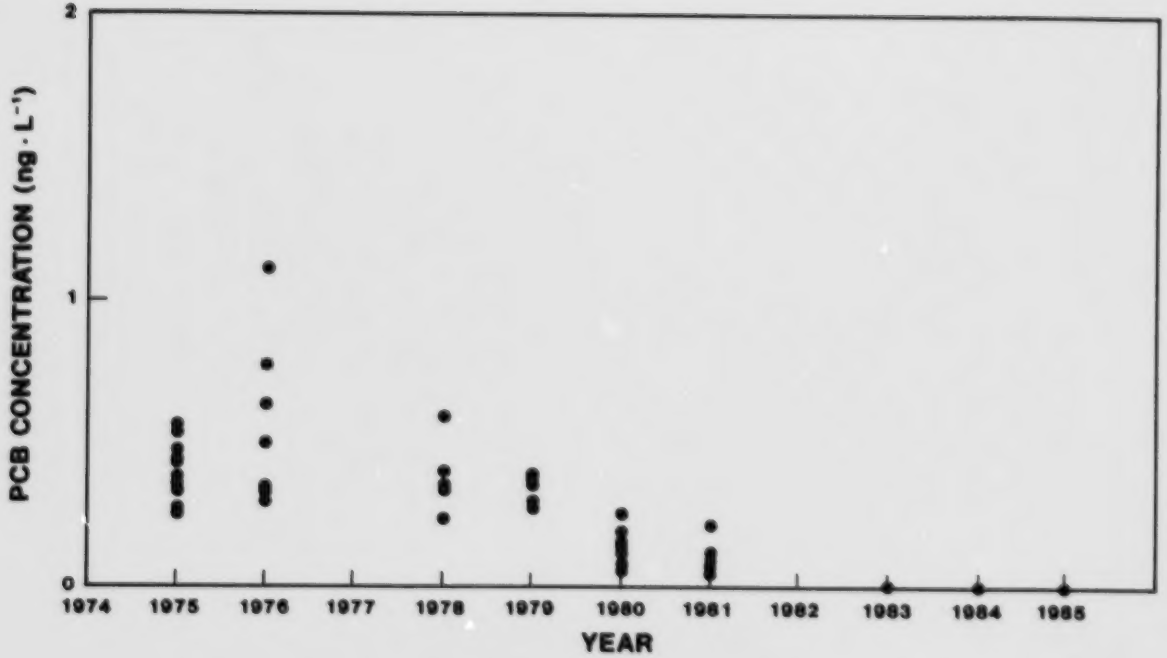

FIGURE 4. TRENDS IN PCB RESIDUES IN SEAWATER OF THE PACIFIC AND INDIAN OCEANS, COVERING THE AREA 80°N-80°S, 40°E-100°W, DURING THE PERIOD 1975-1985. (FROM TATSUKAWA, UNPUBLISHED DATA)

ozone layer that protects life on earth against damaging solar ultraviolet rays. Chlorofluorocarbons have been of little direct consequence themselves to the marine environment, however, because they have a low solubility in seawater, are quite inert and have a comparatively low toxicity.

Dioxins and furans have emerged as organochlorine compounds of great concern during the late 1980s. They are unwanted by-products of combustion, herbicide (2,4-D and 2,4,5-T) and fungicide (tetra- and pentachlorophenol) production and of the combination of chlorine, used in bleaching pulp, with organic substances released in pulpmill wastes. They are also highly toxic. Their presence was not identified until the early 1980s because of lack of suitable analytical technology. The presence of dioxins, particularly the highly toxic 2,3,7,8-tetrachlorodibenzodioxin (2,3,7,8-TCDD) at a concentration exceeding 20 parts per trillion, wet weight, in crustacean shellfish in the vicinity of pulpmills in Howe Sound, British Columbia, led to closures of shrimp, prawn and crab fisheries in these areas on 30 November 1988. The crab fishery near the pulpmill in Prince Rupert was also closed on that date, owing to high dioxin levels, particularly in the crab hepatopancreas. Closures were extended to cover all of Howe Sound for crabs, and larger areas than previously for shrimps and prawns within Howe Sound on 14 June 1989 (Figure 5). Other coastal areas of British Columbia, in the vicinity of pulpmills and sawmills, were closed for harvesting of crabs, prawns and shrimps, and in two areas for oysters, on 23 November 1989 (Figure 6).

The Waste Management Branch of the British Columbia Ministry of Environment has developed a new regulation under the Waste Management Act that requires the 17 British Columbia mills which use chlorine in the bleaching process to reduce their discharge of chlorinated organic compounds to a maximum of 2.5 kg per air-dry ton of pulp production by 31 December 1991 and to 1.5 kg per ton by 31 December 1994. Comparable requirements will be introduced in federal regulations under the Canadian Environmental Protection Act. A further provincial requirement is that a target of 31 December 1991 be met by all mills for providing secondary effluent treatment. The mills were also required to undertake all immediate measures that will reduce discharges of dioxins to the environment, including elimination of the production of chlorophenol- contaminated wood chips by B.C. sawmills and the use, by pulpmills, of defoaming agents which produce dioxins.

Pulpmills that use chlorine for bleaching pulp have been required by both the federal and provincial governments to produce plans on how they will meet the foregoing deadlines for reducing dioxin and furan discharges to the designated levels. Most mills propose to replace chlorine with chlorine dioxide as a bleaching agent. Some mills will introduce oxygen as a replacement for chlorine.

It is uncertain how long the British Columbia crustacean fisheries will remain closed. Even after dioxins and furans cease to be discharged from the mills, residues of these compounds will remain in the sediments. The mode of entry of dioxins and furans into marine organisms from the sediments is not understood well enough to enable us to predict how long marine organisms would be expected to bioaccumulate these substances from the sediments. Besides pulpmills as a source of dioxins and furans, there is at least one location (Cowichan Bay), where a sawmill appears to be the cause of elevated levels of dioxins in crabs. There is also one location (Kitimat Arm), where the source has not been identified. A pulpmill in the area does not use chlorine for bleaching the pulp it produces.

The haunting question is whether there are other highly toxic compounds being inadvertently produced by industry, released into the environment and

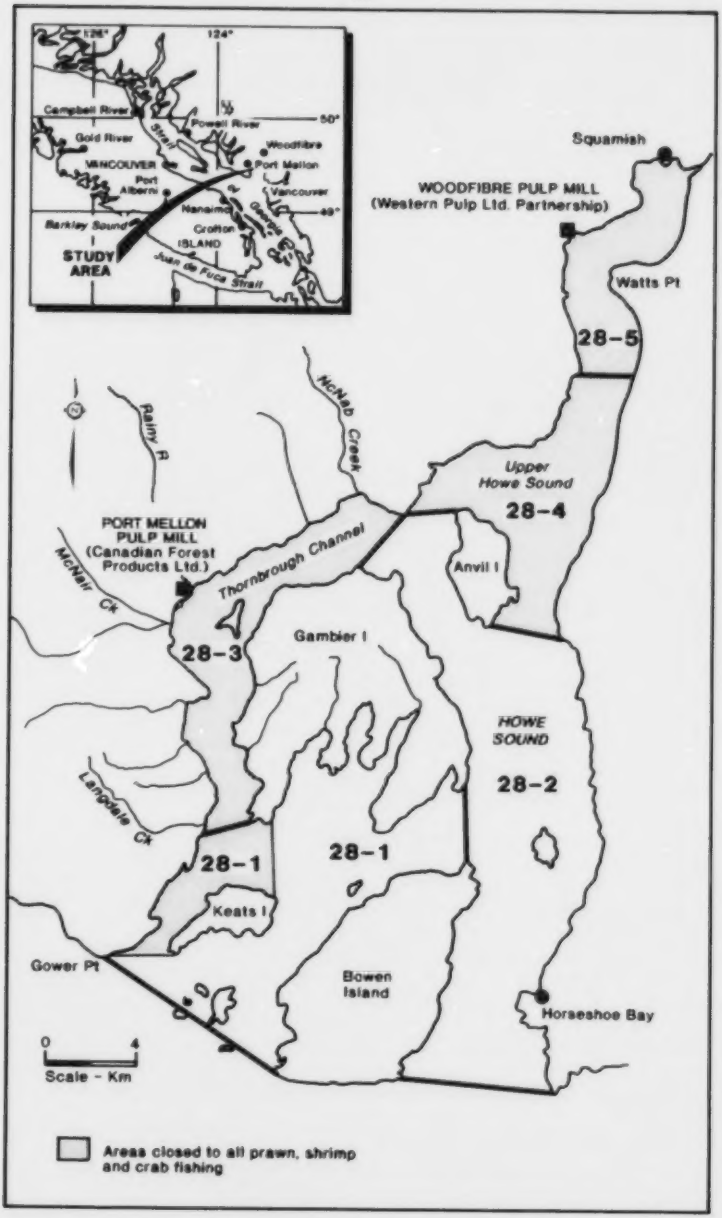

FIGURE 5. MAP OF HOWE SOUND, BRITISH COLUMBIA, SHOWING THE TWO PULPMILLS AND THE CLOSURES FOR CRABS, PRAWNS AND SHRIMPS, 14 JUNE 1989.

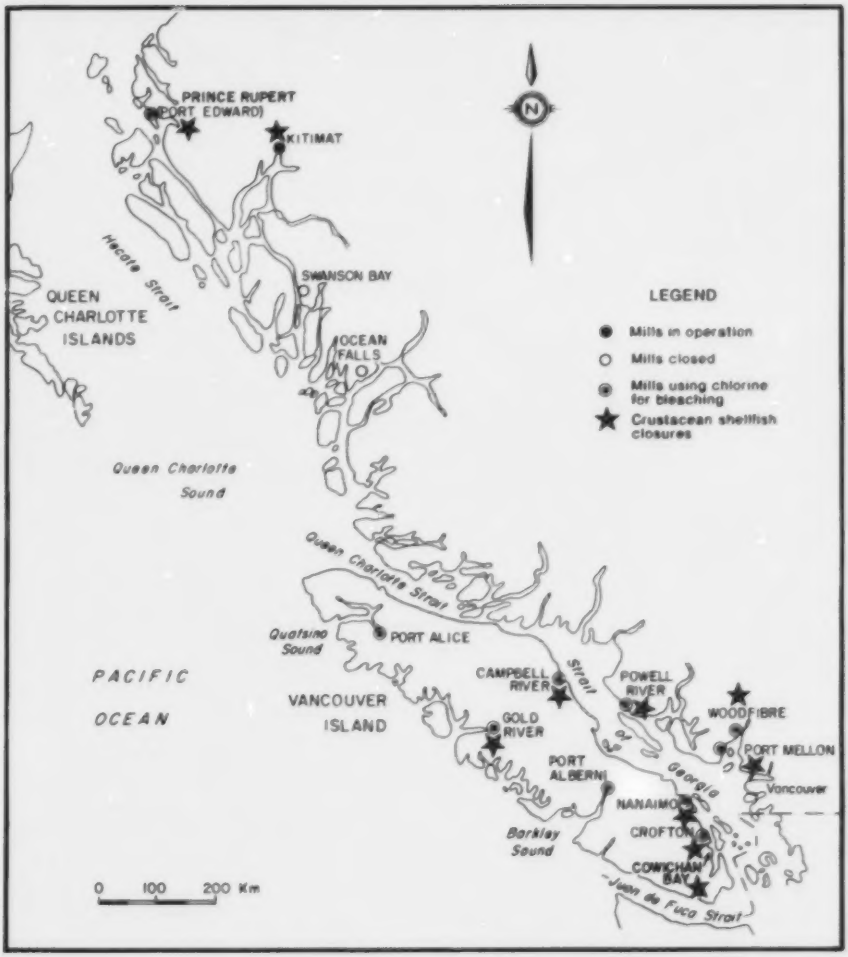

FIGURE 6. MAP OF LOCATIONS OF EXISTING AND CLOSED PULPMILLS ON THE COAST OF BRITISH COLUMBIA, SHOWING MILLS USING CHLORINE FOR BLEACHING, AND CLOSURES OF FISHERIES FOR CRUSTACEAN SHELLFISH, 23 NOVEMBER 1989.

bioaccumulated by marine organisms which we have not attempted to identify or have not been able to measure.

4. Metals

Metals originate from a wide variety of sources, including natural weathering of metal-containing rocks and soils, mining operations, smelters, metallurgical plants, electroplating facilities, photographic laboratories, thermal-power-generating plants and combustion of lead-containing gasolines. Metals enter the marine environment through rivers, urban and agricultural runoff, municipal wastewater outfalls, ship discharges and by way of the atmosphere.

The oceans contain metals originating from natural sources, such as weathering of minerals on land, that have been entering the seas with river water since primordial time. While metals appear in above-background concentrations in seawater of inshore areas, particularly where industry contributes metal-rich effluents, there is little evidence in the open ocean for concentrations of metals that exceed natural background levels by a significant margin. Metals tend to become adsorbed onto particulate matter in seawater and eventually settle to the bottom to become incorporated into the sediments, as shown in Figure 7. Metals generally show an increasing concentration in seawater with depth (Bruland, 1983).

The one exception to metals exhibiting an increasing concentration in seawater with depth is lead, which has been shown to be present at substantially higher levels than background at the sea surface (Figure 8) (Schaule and Patterson, 1980). This is presumed to be due to atmospheric input of lead from combustion of leaded fuels. With the reduction of lead in gasolines, imposed by regulations, there is evidence for a decline in lead concentration in such major streams as the Mississippi River (Trefry *et al.*, 1985), as well as in the marine environment, as suggested by corals off the southeastern USA. A two-fold decline in fluxes of aeolian lead inputs to North Atlantic surface waters during 1970 to 1980 has shown up in coral growth layers, and this is probably associated with the decline in alkyl lead combustion in the USA (Patterson and Settle, 1987).

To be of consequence ecologically and from the human health point of view, metals must be biologically available (Waldichuk, 1985). A large proportion of the total metals found in the marine environment does not enter into biological processes. Metals in the particulate form are essentially inert. Some of these metals may go into solution when exposed to the acidic conditions in the gut of marine organisms when ingested. In general, metals present in seawater in the dissolved form are more likely than the particulate form to have a biological effect on marine organisms and to be incorporated into their tissues.

In Canada, we have had some experience in disposal of mine tailings into the sea. Tailings are basically the pulverized waste rock from the ore after the desired metals have been extracted from it. They have been dumped into the sea from a number of coastal mines in British Columbia which are now closed. But one copper and molybdenum mine (Island Copper Mine at Port Hardy) continues to operate on the northwest coast of Vancouver Island (Figure 9) and disposes of about 50,000 tons of tailings daily into Rupert Inlet. One of the concerns about disposal of these tailings was that metals would be leached from them and bioaccumulated by marine organisms (Waldichuk and Buchanan, 1980).

An exposure experiment was conducted with the mussel, *Mytilus edulis*, and the mud clam, *Macoma balthica*, at different temperatures and salinities to determine the uptake of lead from Island Copper Mine tailings over a 30-day period (McGreer *et al.*, 1980). The exposure experiment included also tailings

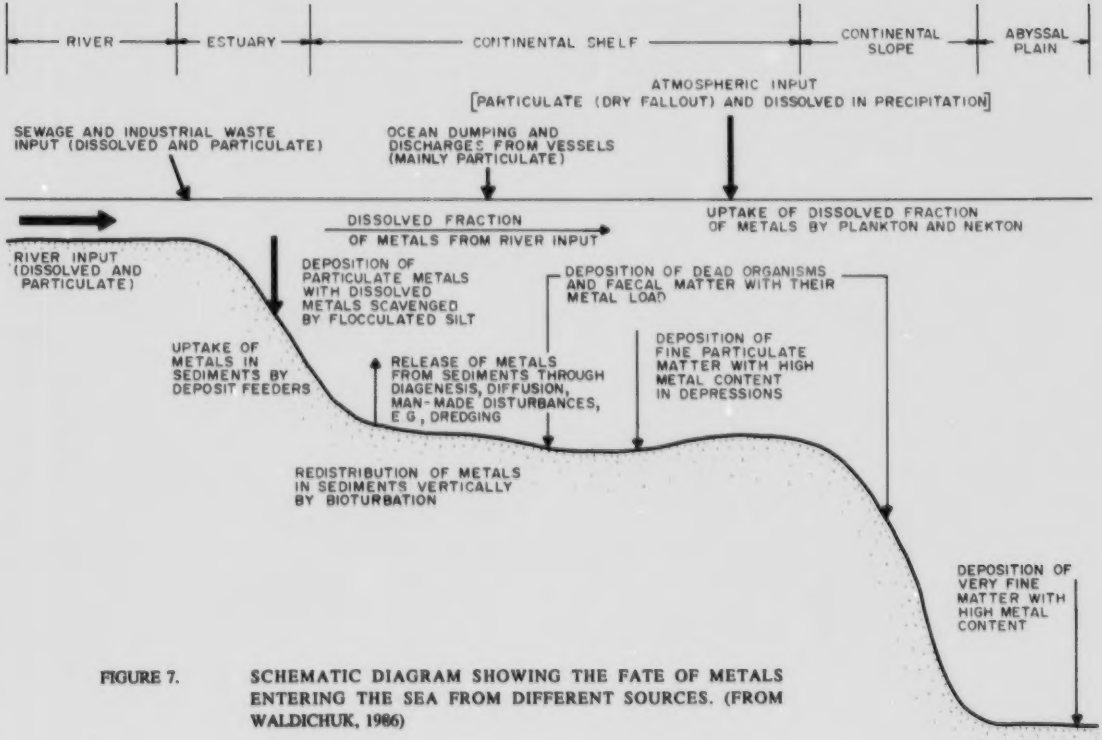

FIGURE 7. **SCHEMATIC DIAGRAM SHOWING THE FATE OF METALS ENTERING THE SEA FROM DIFFERENT SOURCES. (FROM WALDICHUK, 1986)**

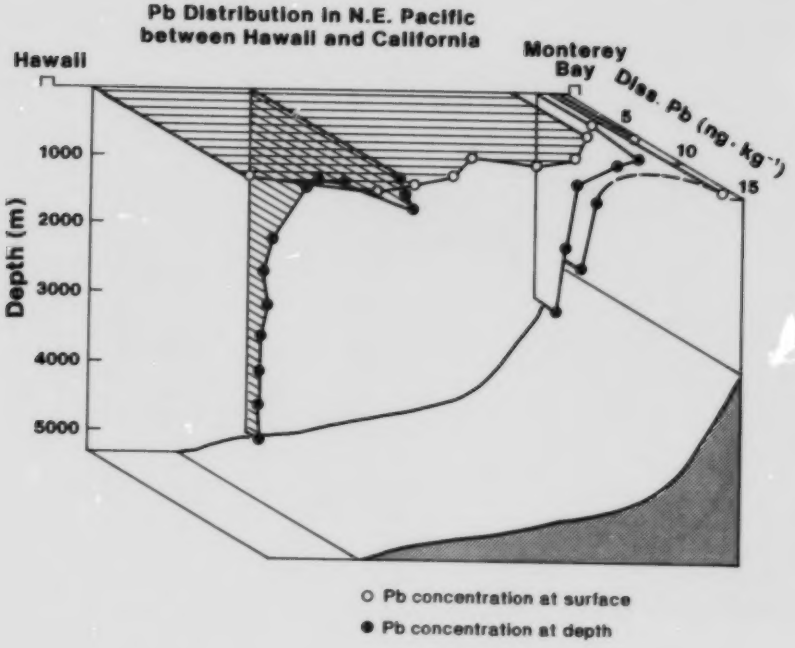

FIGURE 8. DISSOLVED LEAD DISTRIBUTION IN SEAWATER OF THE NORTHEAST PACIFIC OCEAN. (FROM SCHAULE AND PATTERSON, 1980)

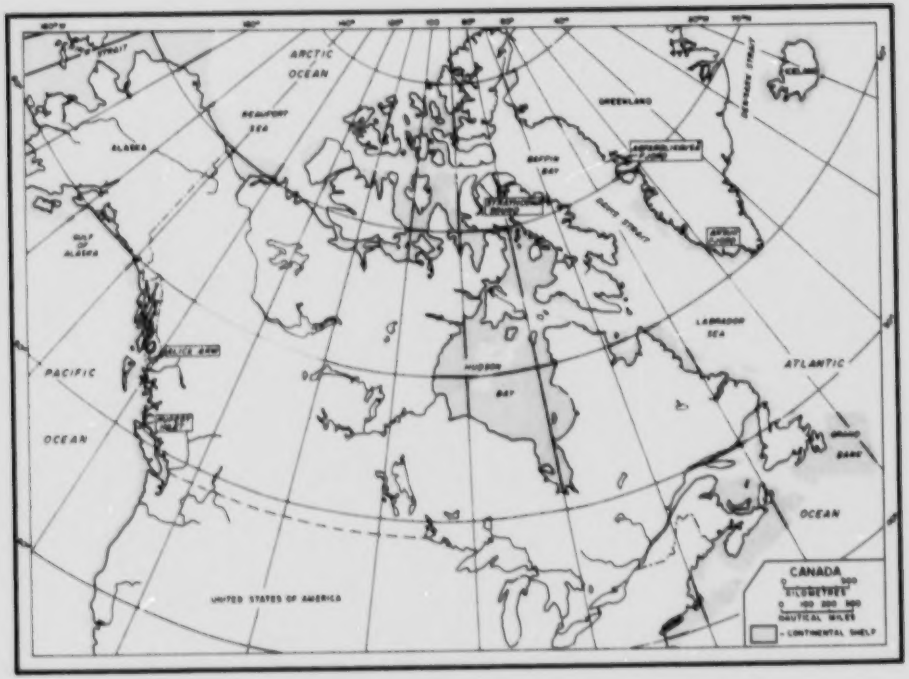

FIGURE 9. MAP OF CANADA AND GREENLAND, SHOWING LOCATIONS OF MINES WHERE TAILINGS ARE OR HAVE BEEN DISCHARGED INTO THE SEA, OR INTO A LAKE DISCHARGING INTO THE SEA. (FROM WALDICHUK, 1988)

from the Nanisivik Mine on Baffin Island in the Northwest Territories, which disposes of its tailings into a lake draining into Strathcona Sound, and from the Greenex Mine on the west-central coast of Greenland, where the tailings are discharged into Agfardlikavsa Fjord. The results (Figure 10) showed a comparatively low uptake of lead from tailings of the Island Copper Mine, with very much higher uptake from tailings of the Greenex Mine (note that the concentration is shown on a log scale), and an uptake from the Nanisivik Mine tailings that is only slightly higher than that for the Island Copper Mine tailings. It is obvious that the lead is more soluble, and hence more rapidly bioaccumulated, in the Greenex Mine tailings than in either the Island Copper or Nanisivik tailings.

Some metals, when present in high enough concentrations, are quite toxic to marine plants and animals. Certain forms of metals are particularly toxic to humans. A good example of this is the methylated form of mercury, which contributed so tragically to human fatalities and irreversible neurological disorders in the so-called Minamata disease in Japan (Irukayama, 1967). A somewhat different form of metal poisoning occurred in the Japanese *Itai itai* disease, which was a painful affliction of the bone due to a deficiency of calcium caused by excessive injection of cadmium (Shigematsu, 1973). This was not a marine pollution problem, however, but rather it was due to freshwater contamination. The excessive cadmium arose from contamination of irrigation water by mine effluents used in rice cultivation.

In British Columbia, zinc contamination of oysters resulted from the discharge of pulpmill effluents containing excessive concentrations of zinc from the use of zinc dithionite (known as zinc hydrosulphite in the trade) for brightening of groundwood pulp used for newsprint (Waldichuk, 1974). By 1973, the pulp and paper industry in British Columbia decided to replace zinc dithionite with sodium dithionite as a brightening agent, after it was shown that zinc was present in extremely high concentrations in some of the coastal oysters near pulp and paper mills that had used the zinc compound.

This was not the first time that the pulp and paper industry in British Columbia had taken the initiative to eliminate contamination by a toxic substance. The industry at one time used an organic mercurial compound to control slime mold of a *Penicillum* species at its paper machines. Then the U.S. Food and Drug Administration introduced a regulation requiring that paper products that might be used for wrapping food must show zero mercury residues. Because a large proportion of British Columbia's pulp and paper products was exported to the USA, the industry decided not to risk contamination with mercury and switched to other anti-fungal agents, such as pentachlorophenates. Of course, the replacement chemicals later led to other problems, but in the meantime, at least they eliminated the risk of contamination of paper products by mercury. The early use of mercury compounds in pulp and paper mills, however, left a problem of high mercury contamination in sediments that had to be dealt with in disposal of dredged material from these areas under the Ocean Dumping Control Act of 1975 (now Part VI of the Canadian Environmental Protection Act, as of 30 June 1988).

Prior to 1970, copper-based paints were widely used to protect the bottoms of ships and smaller vessels against fouling by algae and encrusting marine fauna. Such use raised concerns about the toxic effect of copper leached from these paints on organisms in non-target areas. Hence, an effective replacement for copper was found in tributyl tin (TBT) for anti-fouling paints. The new metallic additive became widely utilized in paints not only for the bottoms of boats, but also for anti-fouling treatment of nets used for holding fish in fish pens in aquaculture. TBT was soon found to have highly undesirable effects on oysters and other marine species. It led to a significant reduction in

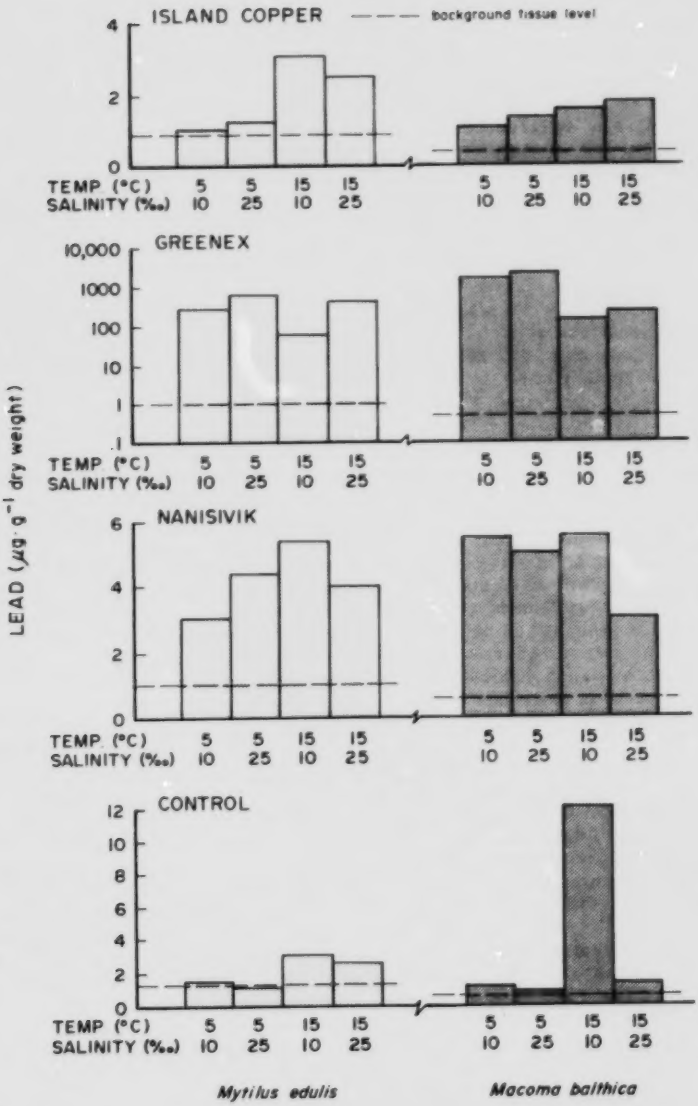

FIGURE 10. UPTAKE OF LEAD FROM SEAWATER EXPOSED TO DIFFERENT MINE TAILINGS BY THE BIVALVES, *MYTILUS EDULIS*, AND *MACOMA BALTHICA*, UNDER DIFFERENT SALINITIES AND TEMPRATURES. (FROM McGREER *ET AL.*, 1980)

reproductive success in oysters (Thain and Waldock, 1986), and to shell thickening in adult oysters that rendered them unmarketable for the halfshell trade. Residues of TBT were also found in salmon held in pens with nets treated by TBT-based paint (Davis and McKie, 1987). Tributyl tin is now either banned or restricted in several countries, including Canada, for use as an anti-fouling additive for paints applied to hulls of boats and nets of fish pens. A suitable, universally-acceptable replacement for TBT has not yet been found, but there is a move in some quarters back to copper-based paints.

Phosphorus is usually regarded as an unlikely metal to cause pollution problems. But it led to an unusual pollution condition in Long Harbour of Placentia Bay, Newfoundland, in the spring of 1969 (Idler, 1969; Jangaard, 1970). The yellow phosphorus was released by a fertilizer plant in Long Harbour and formed a colloidal suspension in the seawater of Placentia Bay. It resulted in an outbreak of "red herrings", in which the fish exhibited a red discolouration due to a haemolytic condition of the skin caused by the intake of phosphorus. The effect of the phosphorus proved to be fatal to a certain proportion of the herring exposed to the phosphorus. The phosphorus was found to be toxic also to other species such as Atlantic salmon, lobsters and beach fleas (Zitko *et al.*, 1970). Once corrective action was taken to prevent the release of phosphorus from the fertilizer plant into the sea, the herrings ceased to exhibit the red discolouration and other evidence of contamination by phosphorus in Long Harbour disappeared (Addison *et al.*, 1972).

Cadmium contamination became a problem in Atlantic Canada during the early 1980s. Leaching of a tailings pile from a zinc-lead smelter led to high concentrations of cadmium in Belledune Harbour (Uthe and Zitko, 1980). The cadmium was obviously present in a biologically available form, because lobsters in Belledune Harbour were found to have high cadmium concentrations in their tomalley (digestive gland). A closure was imposed by the Department of Fisheries and Oceans on lobsters harvesting in Belledune Harbour in 1980. After certain ameliorative measures were taken to reduce the input of cadmium into Belledune Harbour, the levels of cadmium in the seawater and in the lobsters dropped. A 97% reduction in the metals discharged in the liquid effluent was achieved after 1981, and metal concentrations in the mussels and lobsters decreased in response to the reduction of metals input (Hildebrand, 1984). The lobster fishery was reopened in 1985, under an initial arrangement whereby only the white meat would be marketed. As the cadmium concentration in the tomalley reached an acceptable level, it would also become marketable.

5. Radionuclides

Radionuclides are toxic, plutonium being regarded as the most toxic substance known to humanity. They also have the property of radioactivity, wherein the radiation emitted can cause genetic and somatic damage to plant and animal cells.

The main source of radionuclides globally has been fallout from atmospheric and subsea nuclear weapons tests from 1945 to 1963 (NAS, 1971). Since the Partial Test Ban Treaty of 1963, which prohibited atmospheric and subsea testing of nuclear weapons by the signatory nations (major nuclear powers), there has been a steady decline in the concentrations of radionuclides in the marine environment, as exemplified by strontium-90 and cesium-137 in the surface water of the North Pacific (Figure 11) (Miyake *et al.*, 1978). The comparatively high concentrations observed from 1957 to 1959 were apparently a result of a large series of hydrogen bomb explosions, the so-called Castle Tests, conducted by the USA on the ground surface of the Bikini-Eniwetak atolls in the tropical Pacific during March-May 1954. While nuclear reactors provide some local environmental input of radionuclides, they have not made significant

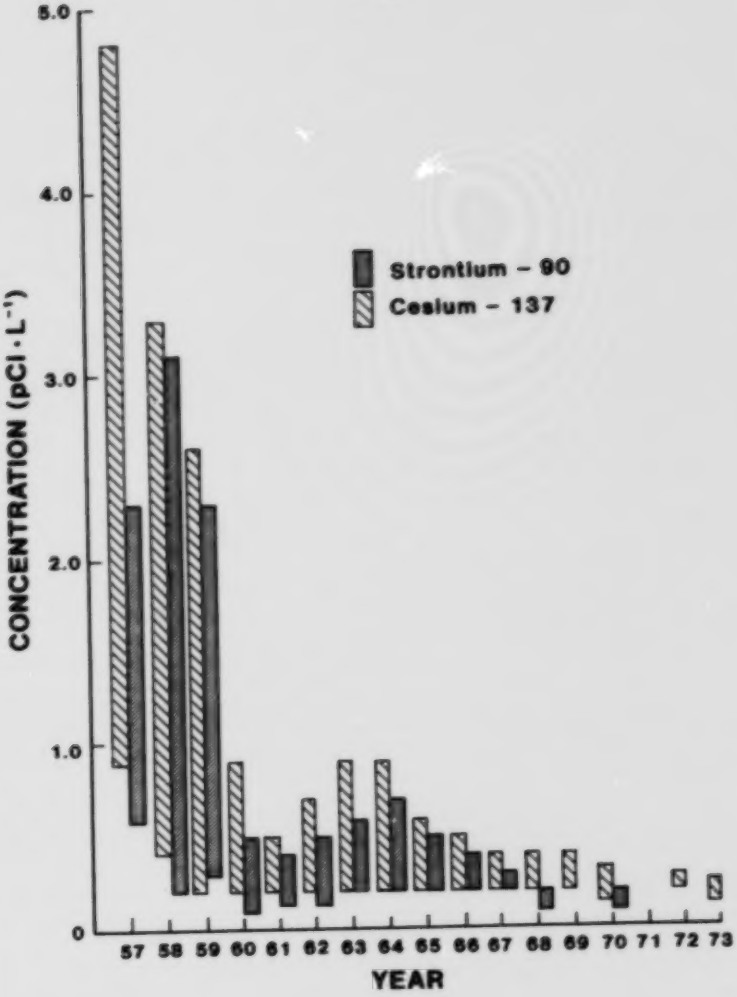

FIGURE 11. YEAR-TO-YEAR VARIATIONS OF RANGES OF STRONTIUM-90 AND CESIUM-137 CONCENTRATIONS IN THE WESTERN NORTH PACIFIC OCEAN, FROM 1957 TO 1973. (FROM MIYAKE *ET AL.*, 1978)

global contributions of radioactivity when operating normally. The Chernobyl disaster of 1986 contributed a globally-significant amount of radionuclides, but this addition was comparatively short-lived.

In Atlantic Canada, the radioactivity in the Bay of Fundy arising from the Point Lepreau nuclear reactor in southern New Brunswick is being carefully monitored. So far, there is little evidence of any significant increases in marine radioactivity from this nuclear-power facility, which is due in part to the type of non-water-cooled reactor (CANDU) in the installation (Eaton *et al.*, 1986).

Two nuclear power facilities that have contributed more radionuclides to the marine environment than the Point Lepreau plant are the Hanford Works on the Columbia River in eastern Washington State, USA, and the Windscale Works in Sellafield on the Cumbria coast of northwest England. Reactors at these facilities use cooling waters, which are discharged, in the first case, into the Columbia River, and in the second case, into the Irish Sea. At the Hanford Works, eight of the power reactors, which contributed much of the chromium-51 and other radioactive contamination in the Columbia River, were closed down in 1971. There is only one power reactor and a research reactor remaining in operation at Hanford (Jacquish and Mitchell, 1988). The radioactive contributions from these two reactors to the Columbia River, the Columbia River estuary and to the North Pacific Ocean are now very small. The river is monitored for radionuclides near the Hanford Works, but not in the estuary nor in the Pacific Ocean beyond the estuary.

The Sellafield facility, on the other hand, continues to operate at nearly a full-scale level and continues to discharge its effluent into the Irish Sea. The marine contamination caused by this nuclear-power site has been reviewed by Woodhead (1984). In recent years, a spent-fuels reprocessing plant for plutonium has been added at Sellafield, and the amount of radioactive waste produced would have been expected to increase. Monitoring for radionuclides in the Irish Sea and in other coastal waters of the United Kingdom is conducted by staff of the Ministry of Agriculture, Fisheries and Food and reported regularly (e.g., Hunt, 1989). Radiation exposure of the public from the Sellafield discharges, by consumption of fish, is still predominantly due to radiocesium. But this is well within the does limits prescribed by the International Commission on Radiological Protection. The contribution to the collective dose of the public due to Sellafield is expected to decline, reflecting the decreasing discharges during the past decade, particularly following the installation of the ion-exchange effluent plant, which commenced operation in May 1985. Reduction in discharges of radiologically significant nuclides are planned when the enhanced actinide removal plant commences operation, scheduled for 1992 (Hunt, 1989).

At present, no nuclear wastes in a contained form are officially deliberately dumped into the Sea. Disposal of low-level radioactive wastes at various sites off the Atlantic, Pacific and Gulf coasts of the USA was phased out during the early 1960s. Canada never officially disposed of radioactive materials at sea. Disposal of low-level radioactive wastes from European nuclear facilities was phased out in 1986, as a result of a resolution of the Consultative Meeting of Contracting Parties to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, held at the International Maritime Organization in London, England, September 1985.

Consideration has been given to burial of high-level radioactive wastes in oceanic subduction zones between colliding tectonic plates, where geological processes over the course of time would be expected to convey the wastes into the bowels of the earth. Research has been proposed to study this option for high-level waste disposal. It is uncertain how well advanced any serious

planning is for such disposal, and how acceptable this approach would be internationally.

In the absence of resumption of testing of nuclear weapons in the atmosphere or in the sea, and assuming that nuclear weapons will not be used in warfare, concentrations of radionuclides in the marine environment are expected to level out at a comparatively low level. It is not anticipated that nuclear reactors will add a significant amount of radionuclides to the marine environment globally in the foreseeable future.

CRITICAL AREAS OF THE WORLD OCEANS

Some parts of the world oceans are more vulnerable to pollution than others. This is related to the fact that some marine areas receive contaminants at a greater rate than others. It must also be acknowledged that processes of dilution are more rapid in those areas where currents and mixing processes are stronger than in those where the waters are comparatively stagnant. In other words, the residence time for a particular substance varies for different parts of the global oceans. Of course, vulnerability depends also on the sensitivity to contaminants of the marine resources in a given area. In general, the open oceans can be considered the least vulnerable of marine environments because of the enormous volume of water involved, the horizontal and vertical mixing and transport processes, that exist there owing to strong currents and wave action, and the normal absence of shorelines, where the greatest damage is done by such contaminants as oil.

1. Marginal Seas

The Mediterranean Sea, Black Sea, Baltic Sea, Red Sea, Gulfs Area (Persian Gulf and Gulf of Oman) and the North Sea are considered Special Areas by the International Maritime Organization, from the point of view of pollution from ships. Pollution can arise from the disposal of contaminants in these areas and special precautions are required of vessels plying their waters. The rate of flushing of these seas is comparatively slow. Dilution and dispersion of substances introduced into their waters are much slower than in the open ocean. Areas like the Mediterranean have essentially a negative estuarine circulation, where evaporation exceeds precipitation and runoff, and the net flow in the surface layer through the Strait of Gibraltar is inward. Thus, pollutants tend to be concentrated in the surface layer of the Mediterranean, rather than being flushed out of the system. Parts of the Adriatic Sea exhibit evidence of over-enrichment with nutrients from sewage and are plagued with toxic plankton blooms.

The Baltic Sea, on the other hand, has an excess of precipitation and runoff over evaporation. It tends to be stratified with comparatively low salinity at the surface. However, the exchange through the constricted channels connecting with the Kattegat, the Skagerrak and the North Sea is slow, so that contaminants released into the Baltic Sea require a long time to reach the open ocean. Similar conditions prevail in the other designated Special Areas.

2. Highly Sensitive Ecosystems

Particularly Sensitive Areas have been defined by the International Maritime Organization as those marine areas which need special protection because of their significance for ecological, socioeconomic or scientific reasons and which may be vulnerable to pollution damage by such maritime activities as operational and incidental discharges. These areas include the Great Barrier Reef off Australia, Galapagos Archipelago, Bermuda Islands, Flower Garden Banks in the Gulf of Mexico, Wadden Sea, bird sanctuaries, waters adjacent to sea-turtle nesting beaches and marine-mammal breeding and calving grounds.

Most estuaries, sea-grass beds, salt marshes and mangroves can also be considered as highly sensitive ecosystems. Oil, assorted other toxic substances and suspended sediments could do irreparable damage to the plant and animal organisms in such areas. Every precaution has to be taken to minimize entry of contaminants into these ecosystems.

3. Arctic Ocean

The Arctic is the last place one would expect to find marine pollution, considering the comparative lack of people and industry. Over the course of the last two decades, however, measurements have been made on the concentrations of organochlorine compounds in the ringed seals, polar bears, beluga whales, narwhals and fish (Norstrom *et al.*, 1988; Muir *et al.*, 1988). Levels of PCBs, DDT and chlordane were found to be decidedly higher than expected. Although DDT had been found to decline more than PCBs in eastern Canadian gray seals (*Halychoerus grypus*) and harp seals (*Pagophilus groenlandicus*) during the 1970s (Addison *et al.*, 1984), PCBs were found to have declined more than the DDT-group residues in Arctic ringed seals (*Phoca hispida*) between 1972 and 1981 (Addison *et al.*, 1986). There was some concern that the high levels of organochlorine compounds found in the Arctic recently were due to dismantlement of the DEW (Distant Early Warning) Line in 1985. After further investigation, however, it was found that any contamination that could be attributed to the DEW Line existed only in localized pockets. Minor amounts of organochlorine compounds stem from industrial activities and former Department of National Defence installations in the Arctic and as contaminants in the body lipids of migratory birds. It was concluded, however, that the bulk of the organochlorines have been transported into the Arctic by trophospheric winds from distant places, such as east-central North America, Europe and Asia (Indian and Northern Affairs Canada, 1989). Some of the processes involved in air-sea exchange of contaminants are shown schematically in Figure 12.

The concern in the Arctic is that the contamination has passed through the food chain and ended up in mammals and fish (Muir *et al.*, 1988), which are the main source (70%) of food for native people. There are few options open for locally-produced food sources for the native people of the Arctic. Organochlorine compounds, such as PCBs, exceeded the amount considered as "tolerable" (defined as the amount of contaminant that can be consumed on a daily basis over a lifetime with reasonable assurance of no adverse effects) for 19% of the participants in a study conducted in 1985. In spite of the comparatively high intake of PCBs in traditional Inuit food, a meeting convened in Ottawa, during 28 February-2 March 1989, concluded that the benefits of Inuit foods and of breast feeding to Broughton Island residents in the Arctic outweighed the risk from PCBs (Indian and Northern Affairs Canada, 1989). If marketed foods currently available were substituted for Inuit foods, this would result in a poorer diet and a risk of damage to the Inuits' health. High omega-3 fatty acid levels are found in the traditional Inuit diet and these food constituents are believed to provide protection against heart disease and other health disorders.

It is clear form the foregoing that pollution of the Arctic ecosystem is a serious problem and that it will not be controlled through action taken in the Arctic itself. Because most of it is a result of long-range transport from distant sources through the atmosphere, the pollution can only be stemmed by international treaty. When Prime Minister Brian Mulroney spoke in Leningrad during his visit to the Soviet Union in November 1989, he made it clear that most (75%) of the contamination in the Canadian Arctic was believed to originate in the USSR.

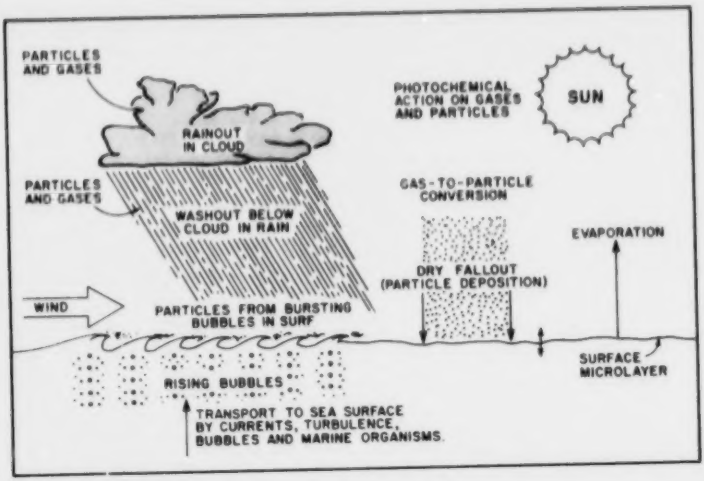

FIGURE 12. SCHEMATIC DIAGRAM SHOWING PROCESSES IN AIR-SEA EXCHANGE OF CONTAMINANTS.

CONTROL OF MARINE POLLUTION BY INTERNATIONAL CONVENTIONS

Considerable advances have been made in the last four decades to control marine pollution by international conventions and other agreements. Some have been clearly quite successful; the effectiveness of others will require some time to evaluate. The main value of certain international conventions is that they have compelled signatory nations to introduce parallel regulations under national legislation that are at least as stringent as those given in the conventions. The following are regarded as some of the more significant global international conventions and agreements.

1. International Convention for the Prevention of Pollution of the Sea by Oil, 1954

Largely superseded by MARPOL 73/78, this convention was developed mainly to control pollution of the sea by oil from ships. The effectiveness of this Convention has never been fully evaluated, but its value has probably been mainly in the contribution it made to national legislation for controlling oil pollution at sea.

2. Partial Test Ban Treaty, 1963

This treaty is seldom regarded as one to control marine pollution. But it has been extremely effective in reducing the amounts of radionuclides in the oceans and in the atmospheres above them. While the major nuclear powers, such as the USA, USSR and UK ratified this treaty, a number of nations with nuclear capability, such as France, China and India, did not. The nations that did not ratify the treaty have continued testing nuclear devices, somewhat infrequently, except for France, which has used its testing grounds at the Muroroa atoll in the South Pacific almost annually for underground testing.

In spite of the occasional atmospheric nuclear weapons tests, with some entry of fresh radionuclides into the marine environment, the amount of radioactive fallout and radionuclides in the marine environment has steadily declined since 1963, reflecting the reduction of atmospheric nuclear debris following the cessation of atmospheric nuclear testing by the superpowers.

3. Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 (London Dumping Convention)

This global convention entered into force in 1975. It prohibits dumping at sea of certain substances, such as mercury, cadmium, halogenated hydrocarbons, oil and plastics, except when present in trace concentrations in such matter as dredged material. High-level radioactive wastes are totally prohibited for ocean dumping. Other contaminants can only be dumped at sea with special care.

The importance of this convention lies mainly in the fact that contracting parties to the convention are obliged to develop national legislation that is at least as demanding in its requirements for pollution control as the convention itself.

4. International Convention for the Prevention of Pollution from Ships, 1973 (MARPOL 73/78).

Modified by a Protocol of 1978, this convention in the main part finally entered into force in 1983. It has five different Annexes: I deals with pollution by oil; II, pollution by noxious liquid substances, such as chemicals; III, hazardous substances carried in packaged form; IV, sewage; and V, ship-generated garbage. The first two annexes are mandatory with ratification of the convention; the last three annexes are voluntary. Annex V entered into force on 31 December 1988 and applies to all kinds of ships. Besides preventing

pollution by the dumping of garbage, one of the most important provisions of the annex is the ban on the dumping into the sea of all plastics, such as synthetic ropes, synthetic fishing nets and plastic garbage bags.

5. Convention on Long Range Transboundary Air Pollution, 1981

Developed to stem the emissions of the precursors of acid rain in one country or countries that are transported by tropospheric winds to other countries, this convention could do a great deal to prevent contaminants, such as PCBs and organochlorine pesticides, from being transported long distances through the atmosphere to contaminate the marine ecosystems in remote areas, such as the Arctic. Implementation can only be achieved through national legislation in countries where atmospheric emissions are produced, that are signatory to the convention. This is difficult to achieve, as noted in the USA, where half of the acid rain precursors that affect Canada are produced.

6. United Nations Convention on the Law of the Sea, 1982.

This convention contains Articles that deal with important marine pollution issues. But it is not yet in force, and even if it does enter into force, important developed nations such as the USA are not likely to ratify it.

7. United Nations Environment Programme 1985 "Montreal Guidelines" on Protection of the Marine Environment
Against Pollution from Land-Based Sources.

Canada participated fully in developing these "guidelines". They can only be effective if participating nations incorporate them into their national guidelines and legislation on protection of the marine environment against pollution from land-based sources.

8. World Commission on Environment and Development, 1987
(Brundtland Commission)

With the release by the Commission of the report "Our common Future" (World Commission on Environment and Development, 1987), nations are beginning to examine seriously the concept of "sustainable development" to see how it can be effectively applied in exploitation of resources. In the marine environment, such established principles as "optimum sustained yield" in fisheries exploitation must be not only adhered to but further refined. The objective of "no net less of habitat" for marine species must be sought in any coastal development where habitats may be at risk. Canada has set up offices on Sustainable Development in the Department of the Environment and in Fisheries and Oceans. Other countries such as the USA are conducting public debates on sustainable development through various fora, e.g., Globescope Pacific Assembly, held in Los Angeles, California, 1-5 November 1989.

FUTURE OUTLOOK ON MARINE CONTAMINATION BY TOXIC SUBSTANCES

Direct, deliberate disposal of toxic substances in concentrated form into the marine environment will not likely occur in future. There will be legislative control by state jurisdictions, and this will probably be strengthened, on sea disposal of matter known to be toxic. Various environmental groups will continue to maintain a close scrutiny on compliance of industry with regulations, e.g., the West Coast Environmental Law Association, Environmental Watch in Howe Sound, British Columbia, and Greenpeace. These groups have certainly watched closely the performance of the pulp and paper industry in British Columbia, particularly in Howe Sound.

Ocean dumping of assorted substances, mainly dredged materials, takes place at present, and will probably continue, in coastal waters of Canada under

Part VI of the Canadian Environmental Protection Act (CEPA). Ocean dumping legislation was first promulgated in Canada in 1975 under the Ocean Dumping Control Act, which was enacted as a response to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 (commonly referred to as the London Dumping Convention) that entered into force in 1975 (Environment Canada, 1989). With the proclamation into law of CEPA on 30 June 1988, the Ocean Dumping Control Act was repealed, and its text and regulations were incorporated into CEPA as Part VI. All applications for ocean dumping are reviewed by a Regional Ocean Dumping Advisory Committee (RODAC) in accordance with regulations under CEPA and guidelines that may have been developed regionally to cope with specific problems, such as dioxins, furans and polycyclic aromatic hydrocarbons. Certain substances, such as mercury, cadmium, halogenated hydrocarbons, petroleum hydrocarbons and persistent plastics, are prohibited, except when present in trace amounts in other materials, e.g., dredge spoils. Other substances are controlled according to their concentrations, conditions that prevail at the ocean dumpsite and living resources that must be protected. The total number of permits issued in 1986, for example, for ocean dumping in coastal waters of Canada was 168, with 96 for the Atlantic Region, 42 for the Pacific & Yukon Region, 20 for the Québec Region and 10 for the Western & Northern Region (Environment Canada, 1989). Over the course of time, the RODACs have become more restrictive with the type of material being allowed for ocean dumping, as reflected in the reduction of total permits issued from a high of 204 in 1978 to only 165 in 1987.

Toxic substances will continue to enter the seas through uncontrolled, non-point sources. Urban and agricultural runoff is difficult to control. It is almost impossible to pinpoint sources of some toxic substances involved in long-range transport through the atmosphere. Anything exposed to the atmosphere, including agricultural and forest sprays, will be transported to distant places by tropospheric winds. A large proportion of the PCBs, DDT and HCH found in the oceans and marginal seas at some distance from land is transported there by winds. Leaks in shore-based installations will always contribute toxic substances to coastal waters before they are sealed. In spite of numerous precautions taken by freighters and tankers, maritime accidents will continue owing to human error and uncontrollable causes. Toxic chemicals carried in bulk by ships will continue to pose a risk of spillage in the event of a collision or grounding.

Toxic substances are released through leaching of chemicals used as herbicides and fungicides, where they may be present as impurities. There has always been concern about the presence of dioxins in the herbicides 2,4-D and 2,4,5-T. Sawmills along the British Columbia coast have contributed dioxins and furans to coastal waters, because they used polychlorophenols as anti-sapstain chemicals. Leachates have contaminated the coastal sediments, and depending on how rapidly dioxins and furans are released into the water from the sediments and eventually flushed out of coastal waters, it may be a long time before the areas, closed for harvesting of crabs, prawns and shrimps, will be reopened.

Dioxins and furans have been entering the marine environment in varying degrees for a long time. They most certainly must have been present in the vicinity of pulpmills since the use of chlorine for bleaching pulp was initiated. The reasons that dioxins and furans have been identified in marine sediments and tissues in coastal waters of British Columbia only relatively recently were: (1) a conscious effort was made to measure them; and (2) analytical technology has advanced sufficiently in the last few years, so that dioxins and furans could be measured at the parts per trillion level. When levels of dioxins and furans clearly exceed those considered safe for human consumption, then there is no alternative than to close the areas for fishing, as was done for those parts of

the British Columbia coast where there was an excessive dioxin level in crustacean shellfish, particularly where 2,3,7,8-TCDD exceeded the safe limit of 20 ppt. The haunting question is: "How many other highly toxic substances are being inadvertently produced by industry that we have not attempted to measure, or indeed are incapable of measuring?"

DISCUSSION

Protection of human health is paramount in managing the marine environment against contamination by toxic substances. Levels of contaminants in organisms considered hazardous to human health may not necessarily be a threat to the organisms themselves. In general, if put into a clean environment, the organisms contaminated by such compounds as dioxins and furans will ultimately cleanse themselves of these contaminants. An exception to this is the contamination of marine mammals. High concentrations of PCBs and other organochlorines can lead to reproductive failure (Helle *et al.*, 1976; Addison, 1989). There is some circumstantial evidence at least that belugas in the St. Lawrence and Saguenay Rivers actually exhibit certain health problems, such as liver tumours and bladder cancer, because of high levels of organochlorines and polycyclic aromatic hydrocarbons (PAHs) in their tissues (Martineau *et al.*, 1985; Massé *et al.*, 1986). Another possible exception is the contamination of bottom fish by PAHs, which may cause irreversible damage in the form of skin tumours and pre-cancerous liver lesions (Goyette and Boyd, 1989).

While the problems of toxic substances, such as dioxins and furans on the coast of British Columbia and PCBs in the Arctic, are mainly a cause for concern about human health, there are some areas where toxic substances create a direct pollution problem for marine organisms and ecosystems. These include estuaries, shellfish beds, salt marshes, sea-grass meadows, coral reefs and mangroves. Toxic substances may cause mortality among individual organisms, but in some cases, e.g., coral reefs, the main impact is in destruction of a particular ecosystem. These ecosystems may be important habitats for certain species of fish and invertebrates. If one considers oil as an example of a toxic substance, it is easy to visualize how contamination by oil can be devastating to these ecosystems. Because of the behaviour of oil in the way it generally floats on seawater and coats intertidal areas, it may be considered as one of the major threats to coral reefs, shellfish beds, seagrasses and marshes. Usually when oil hits shorelines, where such ecosystems are present, the mortality among both the organisms that constitute the basic ecosystem and those that inhabit it is high, and the impact can be long lasting.

The impact of toxic substances on marine organisms becomes serious when there is a measurable effect on a population. Mortality due to toxicity of individual organisms may be inconsequential for the population of the species as a whole. But it may be an early warning that a population could be affected in due course. Monitoring discrete stocks over a period of several years with a knowledge of the effect of other factors, such as harvesting and natural environmental changes is required to determine if there is an impact on the population. If communities are affected, with the more sensitive species declining in numbers and the more tolerant species increasing, then it is clear that there is an undesirable effect on the ecosystem.

CONCLUSIONS

1. It is unlikely that in future toxic substances will be deliberately disposed of in the marine environment, except when present in minute concentrations in other materials being dumped at sea, such as dredge spoils.

2. Disposal of all toxic substances into the sea is being increasingly controlled by regulations in national legislation and through international conventions.

3. Certain toxic substances are inadvertently reaching coastal marine waters from accidental spills and leaks. These marine inputs are decreasing as more stringent controls, through regulations, are being placed on operations from which such spills and leaks originate.

4. Atmospheric long-range transport of toxic substances is leading to contamination of areas, such as the Arctic, far removed from the sources of the contaminants. This is creating a health hazard for native people in these remote areas, such as the Inuit in the Arctic, who rely on the contaminated marine organisms, e.g., seals, narwhals, belugas and fish, for their basic food.

5. Certain highly toxic substances, e.g., dioxins and furans, are inadvertently entering the marine environment by leaching from certain sources, e.g., polychlorophenols used as anti-fungal agents for treating wood, where they are present as impurities. They may be produced also through the combination of chlorine, used for bleaching pulp in pulp and paper mills, with phenolic organic substances released in the waste.

6. Polycyclic aromatic hydrocarbons (PAHs) enter the sediments from a variety of sources, such as petroleum hydrocarbons, combustion products from incineration, creosoted pilings, aluminum smelters and coke ovens used in the steel industry. High PAH concentrations in the sediments have been shown to be associated with an elevated incidence of skin tumours and pre-cancerous liver lesions in bottom fish.

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SESSION 1: GLOBAL EMERGING ISSUES

WEDNESDAY APRIL 4TH 1990, 11:00

GLOBAL ATMOSPHERIC CHANGE

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ABSTRACT

During the last three decades, there has been mounting scientific evidence that human activities are altering the chemical composition of the atmosphere on a global scale. The increase in trace gases capable of trapping long-wave infrared heat radiation from the earth has led to serious investigations about possible widespread climatic changes. Significant modifications of the global climate will likely have major impacts on civilization, though their full extent and time of occurrence are not precisely known. Global atmospheric and climatic change is therefore the most far-reaching environmental issue to have emerged at present.

BIOGRAPHICAL RESUME

Mr. Chénard is a scientific advisor attached to the Office of Environmental Affairs (OEA) of the Canadian Department of Energy, Mines and Resources. He received his Master's Degree in Science from McGill University, specializing in limnology. After working as a research associate at McGill on the long range transport of atmospheric pollutants, he joined EMR in 1982 as a marine biologist involved in environmental management of offshore oil and gas activities. He joined the OEA in 1987, where his specific areas of involvement are global atmospheric change and automotive emissions.

RÉSUMÉ

Des données de plus en plus nombreuses recueillies depuis plus de trente ans indiquent que la composition chimique de notre atmosphère se modifie à l'échelle planétaire sous l'influence des activités humaines. L'augmentation des gaz traces capables d'absorber le rayonnement calorique infrarouge diffusé par la Terre a entraîné des études poussées sur les conséquences possibles sur le climat. De tels changements auraient des conséquences profondes sur notre civilisation bien que nous ne pouvons pas encore mesurer avec précision leur portée et leur rapidité. La question des changements atmosphériques et climatiques planétaires apparaît donc comme le problème environnemental le plus vaste à être soulevé à ce jour.

RÉSUMÉ BIOGRAPHIQUE

M. Chénard est un conseiller scientifique du Bureau des affaires environnementales (BAE) du ministère fédéral de l'Énergie, des Mines et des Ressources (EMR). Il a obtenu une Maîtrise ès sciences de l'Université McGill avec spécialisation en limnologie. Après avoir travaillé comme chargé de recherches sur le transport à distance des polluants atmosphériques, il se joignit à EMR en 1982 pour travailler à titre de biologiste marin sur les questions environnementales reliées aux activités pétrolières et gazières en mer. Il occupe son poste actuel au sein du BAE depuis 1987 où il est principalement chargé des dossiers concernant les changements atmosphériques et climatiques planétaires ainsi que les émissions des véhicules automobiles.

INTRODUCTION:

Except for the first nine months or so spent in a liquid environment, we live our lives bathed in a pervasive mixture of gases common to all. The atmosphere provides the right amount of oxygen for us to breathe. Oxygen also combines in the stratosphere to form ozone molecules that shield us from the lethal bombardment of solar ultraviolet radiation. Water vapour and other gases, most notably carbon dioxide, manage to trap enough of the heat reflected by our planet, in the form of long-wave radiation, to maintain an average temperature that allows life to exist. This phenomenon is known as the "greenhouse effect".

The atmosphere is a dynamic medium, changing every day yet repeating recognizeable yearly patterns that determine the success of our food crops and influence our use of energy and materials. It interacts closely with the water, the soil and the living organisms that make up our environment. We extract fossil fuels and minerals from the land to ensure our quality of life. Water, an essential but trace component of the atmosphere, slakes our thirst, supports important food resources and supplies us with energy . We harvest our food and find our medecines in the veneer of life that clings to land and sea. Rocks, water and living organisms are justly considered valuable resources because we couldn't do without them. But what of the air that surrounds us? Human beings can survive five weeks without food, five days without water, but only five minutes without air. For this reason alone, <u>it is time to consider our atmosphere as a vital resource.</u>

There is compelling scientific evidence that human activities are rivalling natural environmental forces that shape our climate on a global scale. Emissions of several trace gases that are byproducts of energy generation, agricultural practices and land use changes are upsetting the equilibrium maintained between the atmosphere, the land, the oceans and the biosphere. The

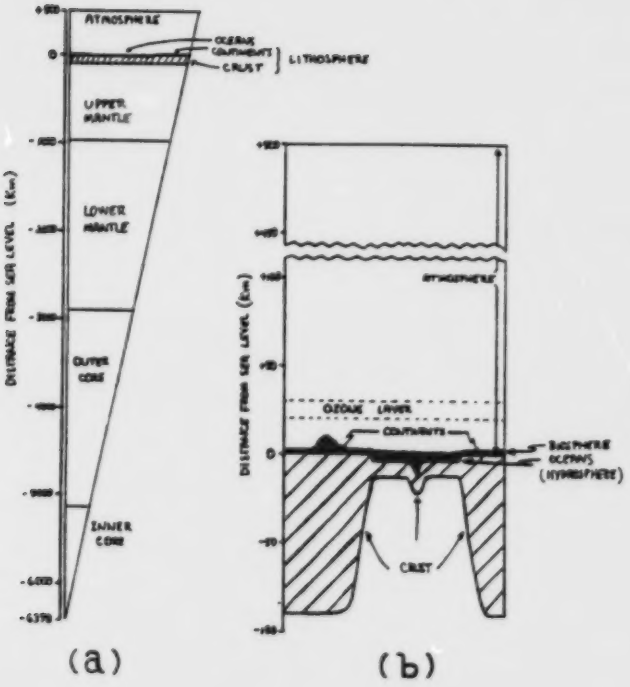

FIGURE 1. SCHEMATIC CROSS-SECTION OF THE EARTH (1A) AND OF ITS OUTERMOST LAYERS THAT SUPPORT LIFE (1B) [REFERENCE 1].

consequences are still uncertain but they are potentially rapid enough and large enough to be considered as serious as natural phenomena if not more so.

1. THE EARTH AND ITS ATMOSPHERE

In cross section, the Earth comprises several major layers of which the atmosphere is the outermost and by no means the thickest (Figure 1). Human activities are confined to a thin section at the surface (Fig. 1a). This zone can be subdivided into four principal domains or "spheres" (Fig. 1b) mainly on the basis of the dominant phase of the matter that comprises them: atmosphere (gas phase), lithosphere (solid phase), hydrosphere (liquid phase) and biosphere (a combination of liquid and solid phases). The biosphere can be represented as a thin coating that extends from the highest mountain summits (8.8 Km) to the deepest ocean depths (- 10.9 Km). The oceans are by far the largest constituent of the hydrosphere with an average depth of 3.8 Km. The thickness of the lithospheric crust varies between 25 and 90 Km beneath the continents, and from 5 to 12 Km beneath the oceans. The average elevation of the continents is about 0.875 Km above sea level.

The atmosphere reaches out almost 500 Km, although nearly all of the gases and other contents are found below 29 Km (Figure 2). Particularities of the Earth's orbit combine with uneven rates of solar heating to produce the circulation that divides the atmosphere into several distinct temperature layers. Most of the variations in climate and nearly all the changes in weather take place in the troposphere, the layer closest to the planet's surface. Man-made emissions are capable of reaching at least the stratospheric ozone layer that extends between 20 and 30 Km altitude (2). (Stratospheric ozone is very diffuse: at sea level temperature and pressure, it would form a layer only 3 mm thick).

The chemical composition of the atmosphere is much more homogeneous than that of the hydrosphere and lithosphere because of faster rates of circulation. After subtracting the 0 to 4% water vapour content, the percentage composition of dry air by volume (up to 20 Kms altitude) is: 78.09% Nitrogen, 20.95% Oxygen, 0.93% Argon, 0.03% Carbon Dioxide; all other gases add up to less than 0.01%.

Atmospheric processes are very rapid compared to most other geological and geophysical phenomena (Figure 3). They occur within time periods that are perceptible by humans. Among the non-atmospheric processes, the only two beyond our control that occur quickly enough to be easily perceived are the 11-year sunspot cycle and sudden catastrophes such as volcanic eruptions and earthquakes. Most of the non-atmospheric processes are beyond direct human control. However, Mankind can add significantly to the forces that shape the global environment through his emissions of pollutants and his changes of land use.

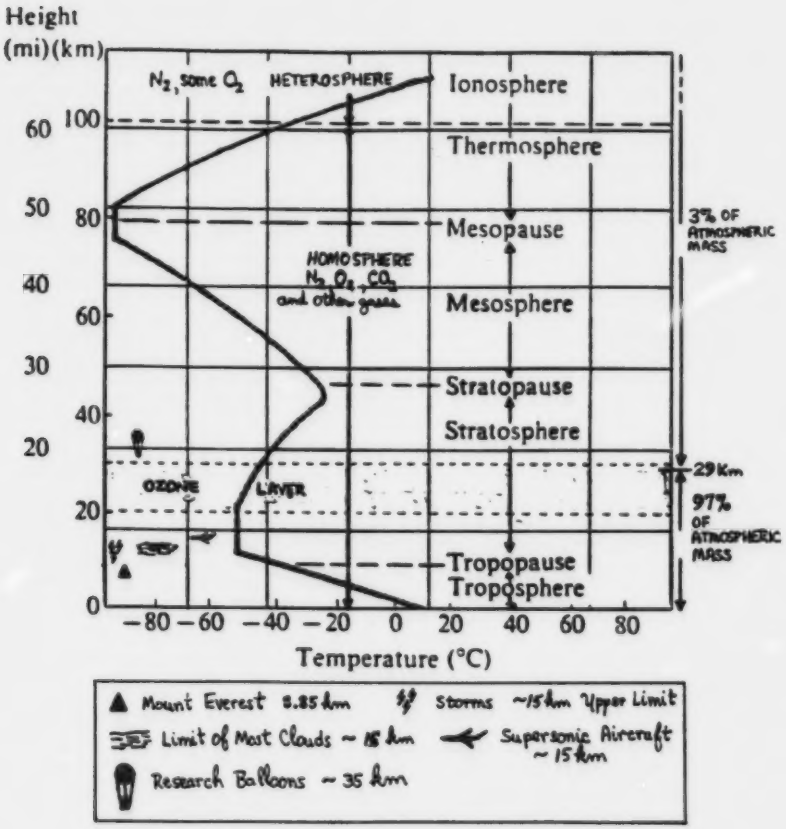

FIGURE 2. SCHEMATIC REPRESENTATION OF THE STRUCTURE AND CHEMICAL COMPOSITION OF THE EARTH'S ATMOSPHERE. THE SOLID BLACK LINE IS THE VERTICAL TEMPERATURE PROFILE [REFERENCE 2].

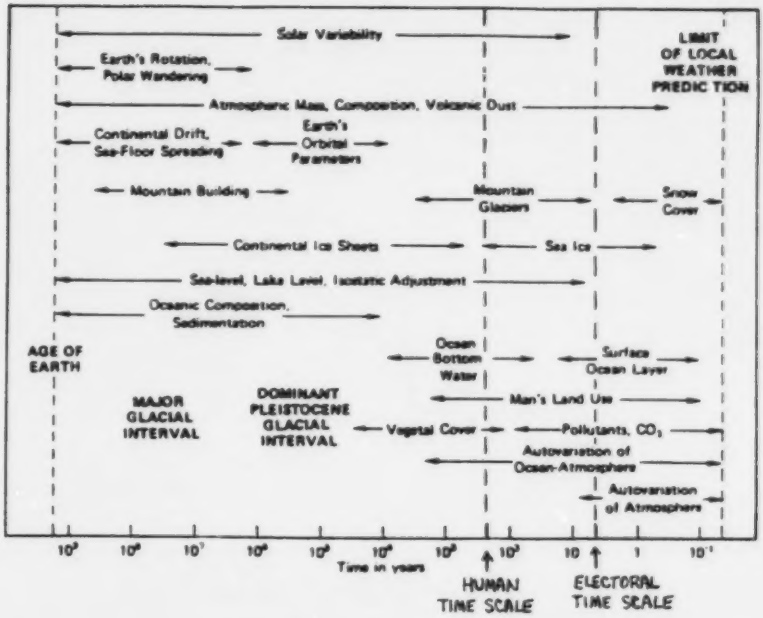

FIGURE 3. TIME SCALES OF THE PRINCIPAL ATMOSPHERIC, GEOLOGICAL AND GEOPHYSICAL PROCESSES THAT SHAPE THE GLOBAL ENVIRONMENT [REFERENCE 3]. TWO REPRESENTATIVE TIME PERIODS PERCEPTIBLE BY HUMANS ARE ADDED FOR COMPARISON PURPOSES. THE ELECTORAL TIME SCALE IS EQUAL TO FIVE YEARS, WHICH IS A GOOD APPROXIMATION OF THE MANDATE OF MOST DEMOCRATICALLY ELECTED GOVERNMENTS. THE HUMAN TIME SCALE CORRESPONDS TO THREE CONSECUTIVE GENERATIONS, ASSUMING AN AVERAGE LIFE EXPECTANCY OF 75 YEARS AND AN AGE OF 25 YEARS AT THE BIRTH OF A FIRST CHILD.

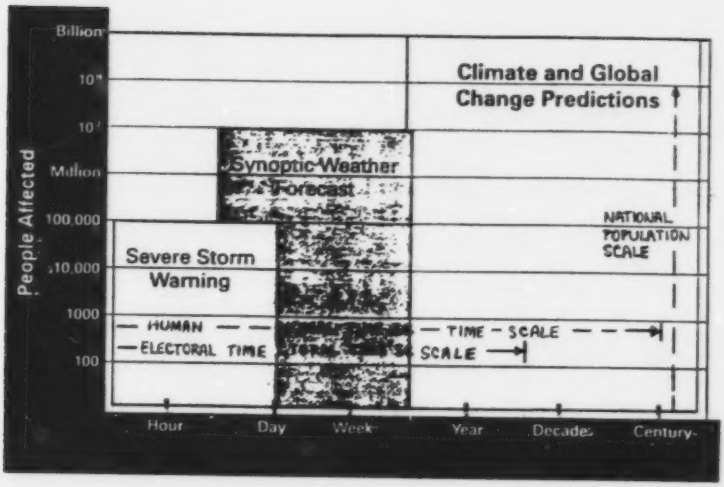

FIGURE 4. THE IMPORTANCE OF ATMOSPHERIC EVENTS AS A FUNCTION OF THEIR DURATION [REFERENCE 4]. THE ELECTORAL AND HUMAN TIME SCALES HAVE BEEN ADDED FOR COMPARISON PURPOSES; FOR THEIR DEFINITIONS, SEE FIGURE 3. THE NATIONAL POPULATION SCALE HAS BEEN ADDED TO PROVIDE A ROUGH IDEA OF THE NATIONAL IMPACTS OF THESE PHENOMENA. MOST DEVELOPED COUNTRIES HAVE A POPULATION ON THE ORDER OF 20 TO 300 MILLION INDIVIDUALS, REPRESENTED HERE BY AN AVERAGE SIZE OF 100 MILLION.

The number of people affected by various atmospheric processes is roughly proportional to their magnitude in time and space (Figure 4). Climate can be defined as the statistical representation of weather over a time period of many years. Changes in global climate could occur quickly enough to have worldwide repercussions during human lifetimes.

2. THE GREENHOUSE EFFECT

The ability of the Earth's atmosphere to maintain a temperature that can sustain life, in comparison to conditions on Mars and Venus, is referred to as the "Goldilocks Problem" by climatologists. Mars is too cold, Venus is too hot, and Earth is just right. Contrary to popular belief, the observed temperatures of Earth and Venus do not differ strictly on the basis of their respective distances from the Sun, but rather according to the abilities of their respective atmospheres to intercept part of the heat that is reflected back towards outer space by the planetary mass. This phenomenon has been dubbed the "greenhouse effect" by comparison with the workings of a greenhouse, though the two are not identical. For the purposes of this discussion, however, it is useful to retain this analogy.

The average global temperature is the result of the balance between incoming solar radiation, mainly at the ultraviolet and visible wavelengths, and outgoing long wave infrared heat radiation given off by the Earth (respectively, the dark and light pathways in Figure 5). The numbers in Fig. 5 are percentages of the total available energy of 342 Watts per square metre. About 240 W/m^2 is absorbed and available to drive climatic processes. Approximately 150 W/m^2 is absorbed at the Earth's surface. This heat balance is mediated by water vapour and trace gases in the atmosphere that are capable of absorbing infrared heat radiation (the gases add up to about 0.04% by volume). These gases are collectively identified as "greenhouse" or "radiatively active" gases, the most abundant of which is carbon dioxide (CO_2). These gases absorb over different portions of the infrared segment of the spectrum (Figure 6). This results in the retention of approximately 84% of the infrared (IR) heat radiation that enters the atmosphere. The radiatively active gases differ not only in the particular wavelengths of IR that they absorb but also in their efficiencies of absorption, expressed per molecule of gas relative to CO_2 (Table 1). They also persist in the atmosphere for different lengths of time (id.). Most of the principal radiatively active gases are partly of natural origin but the two most efficient IR absorbers, chlorofluorocarbons (CFC) 11 and 12, are entirely man-made. They have also been linked to the deterioration of the stratospheric ozone layer.

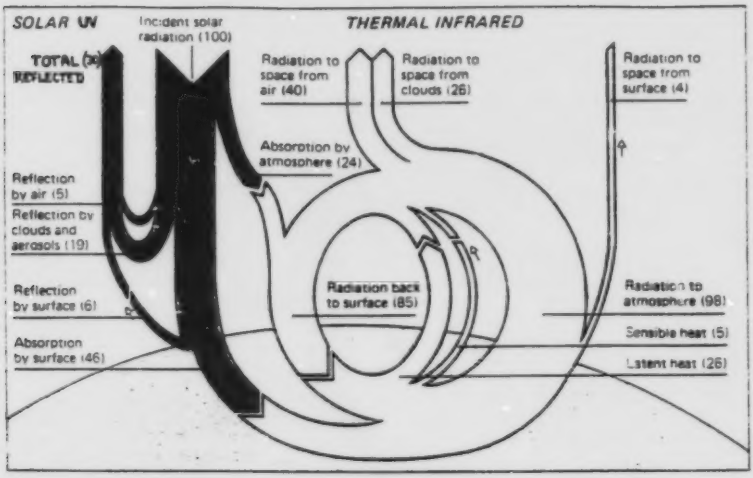

FIGURE 5. DIAGRAM OF THE AVERAGE GLOBAL VERTICAL ENERGY FLUXES. INCOMING SOLAR RADIATION IS REPRESENTED BY THE BLACK PATHWAYS. OUTGOING LONG-WAVE INFRARED HEAT RADIATION IS REPRESENTED BY THE WHITE PATHWAYS. THE NUMBERS ARE PERCENTAGES OF INCOMING SOLAR ENERGY. ABOUT 342 WATTS PER SQUARE METRE REACH THE EARTH; ABOUT 240 ARE ABSORBED AND AVAILABLE TO DRIVE CLIMATIC PROCESSES; APPROXIMATELY 150 ARE ABSORBED AT THE EARTH'S SURFACE. SENSIBLE HEAT IS THE ENERGY FLOWING FROM ONE LOCALE OR MEDIUM TO ANOTHER. LATENT HEAT IS THE ENERGY RELEASED OR ABSORBED DURING A CHANGE OF PHYSICAL STATE (I.E. EVAPORATION OR CONDENSATION OF MOISTURE). FOR THE SAKE OF SIMPLICITY, THE VARIATION OF SOLAR ENERGY FLUX AT DIFFERENT LATITUDES IS NOT SHOWN [REFERENCE 5].

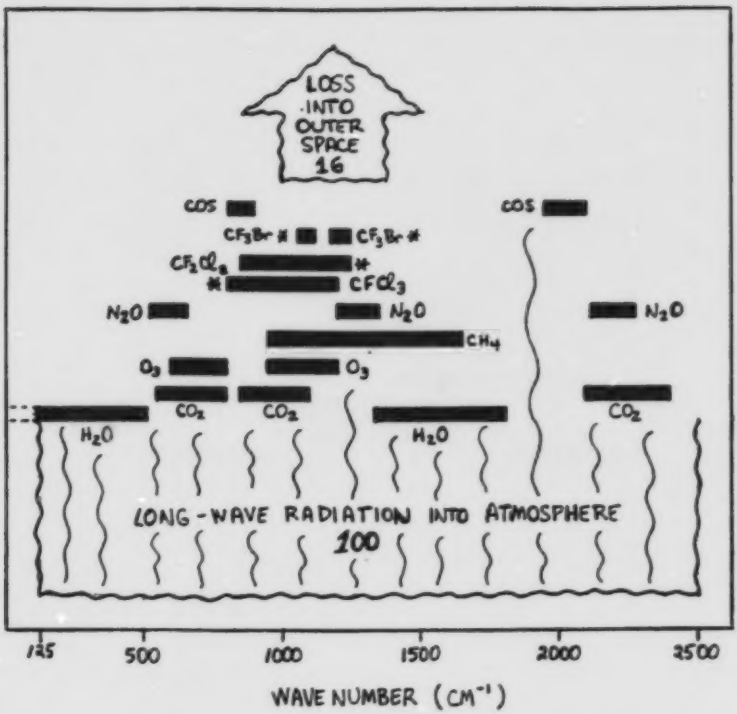

FIGURE 6. SCHEMATIC REPRESENTATION OF THE ABSORPTION OF INFRARED RADIATION BY THE PRINCIPAL "GREENHOUSE GASES". THE WIDTH OF EACH BAR CORRESPONDS ONLY TO THE INTERVAL OF MAXIMUM ABSORPTION OF INFRARED HEAT RADIATION FOR EACH GAS. THE DIAGRAM DOES NOT ILLUSTRATE THE CONCENTRATION OR ABSORPTION EFFICIENCY PER MOLECULE FOR THESE GASES. ABOUT 84% OF THE OUTGOING HEAT RERADIATED FROM THE EARTH'S SURFACE IS INTERCEPTED. THE ASTERISKS IDENTIFY GASES OF WHOLLY HUMAN ORIGIN. IN ADDITION TO WATER VAPOUR (H_2O), THE GASES REPRESENTED HERE ARE: HALON 1301 (CF_3BR), FREON OR CFC-11 ($CFCL_3$), FREON OR CFC-12 (CF_2CL_2), METHANE (CH_4), CARBON DIOXIDE (CO_2), CARBONYL SULFIDE (COS, A MINOR ABSORBER), NITROUS OXIDE (N_2O), AND TROPOSPHERIC OZONE (O_3) [REFERENCE 6].

Were it not for the naturally-occurring greenhouse gases, the average temperature of the Earth would be about 33°C colder than it actually is. Computer models predict that a change in the concentrations of radiatively active gases in the atmosphere will drive the entire global environment to a new equilibrium point, thus bringing about a significant change in the Earth's climate. There is solid evidence that Man-made emissions could be forcing the climate system towards significant warming.

3. GLOBAL CHANGES OF GREENHOUSE GAS CONCENTRATIONS

Since the late Fifties, accurate measurements of radiatively active gas concentrations in the global atmosphere have revealed that these gases are increasing at exponential rates (Figures 7 to 10). Instrumental records for carbon dioxide are the longest, but the trend can be seen for the four other principal greenhouse gases (Table 2). Their different rates of increase probably indicate differences in their production, release, breakdown and removal mechanisms in the global environment. The CFCs are the only ones examined here that can be entirely traced to man-made activities with absolute certainty because they are of entirely synthetic origin. The atmospheric concentrations of carbon dioxide, methane and nitrous oxide can be measured as far back as 160 000 years before present by analyzing air samples trapped at various depths in polar ice (insets in Figs. 7, 8 & 9).

TABLE 1. RADIATIVE POTENCIES AND ATMOSPHERIC RESIDENCE TIMES OF SIX PRINCIPLE RADIATIVELY ACTIVE GASES. THE POTENCIES ARE EXPRESSED RELATIVE TO CO_2 [REFERENCES 6,9,10,11].

GAS	RELATIVE POTENCY PER MOLECULE	RESIDENCE TIME IN YEARS
Carbon dioxide (CO_2)	1	2(atmos. only) 500(atm.& ocean)
Methane (CH_4)	20	10
Nitrous oxide (N_2O)	200	150
Ozone (O_3)	2000	0.2(troposphere)
CFC-11 ($CFCl_3$)	13000	70
CFC-12 (CF_2Cl_2)	20000	110

A comparison with present-day concentrations indicates that we are now experiencing the highest levels of radiatively active gases in the global atmosphere ever determined with instrumental accuracy. The atmosphere is undergoing at this time a perceivable significant change that has no equal since long before any human civilization. It is possible to infer atmospheric composition even further back by interpreting geological proxy indicators of climate, but this is far less

accurate than actual measurements of ancient air samples.

TABLE 2. ANNUAL PERCENTAGE RATES OF INCREASE OF FIVE MAJOR RADIATIVELY ACTIVE GASES, BASED ON INSTRUMENTAL MEASUREMENTS. TROPOSPHERIC OZONE IS NOT INCLUDED HERE BECAUSE OF ITS VERY SHORT RESIDENCE TIME WHICH MAKES GLOBAL ATMOSPHERIC TREND MEASUREMENTS MUCH LESS ACCURATE THAN FOR THE OTHER GASES [REFERENCES 6,9,10].

CO_2	CH_4	N_2O	CFC-11	CFC-12
0.4%	1.1%	0.3%	5.1%	5.5%

The study of ice cores can also yield relative indications of past global temperatures through measurements of deuterium and the ratio of the stable isotopes of oxygen at various depths. Ice that is formed in warmer times is richer in oxygen-18 relative to oxygen-16. The magnitude of this difference is proportional to the temperature difference from present conditions. The Vostok ice core taken in Antarctica shows a very significant covariation between carbon dioxide concentrations and global temperature differences over the last 160,000 years (Figure 11). Given that carbon dioxide plays a critical role in determining heat retention by the atmosphere, and therefore its temperature, it is highly unlikely that this link is coincidental, although an absolute cause and effect relationship has not been proven. Further data of present and past conditions will be necessary to clarify this matter.

What is certain, however, is that the atmosphere is showing signs of unbalance. If the present rates of increase in Table 2 are to continue, we can expect the present concentrations of carbon dioxide to double in roughly 175 years, the one for methane in 63 years, and the one for nitrous oxide in 230 years. These are much faster changes than those deduced from the geological record. The CFCs would double in 13 years, though implementation of the Montreal Protocol or more stringent agreements now being proposed may lengthen their doubling time. The radiatively active gases could also double sooner if there is a further increase of any human activities that result in their emission into the atmosphere. The possible enhancement of the natural greenhouse phenomenon would be the result of the combined effects of all the radiatively active gases. This is related to their concentrations, residence times and their relative molecular capacities to absorb infrared heat radiation. Should the present rates of concentration increase persist, CO_2 would account for about 48% of a projected global temperature increase of 3°C in the year 2030. The other radiatively active gases, mainly the CFCs, would account for the remainder. Mathematical models are not presently capable of accurately predicting the combined effect of all the radiatively active gases on global temperature because of

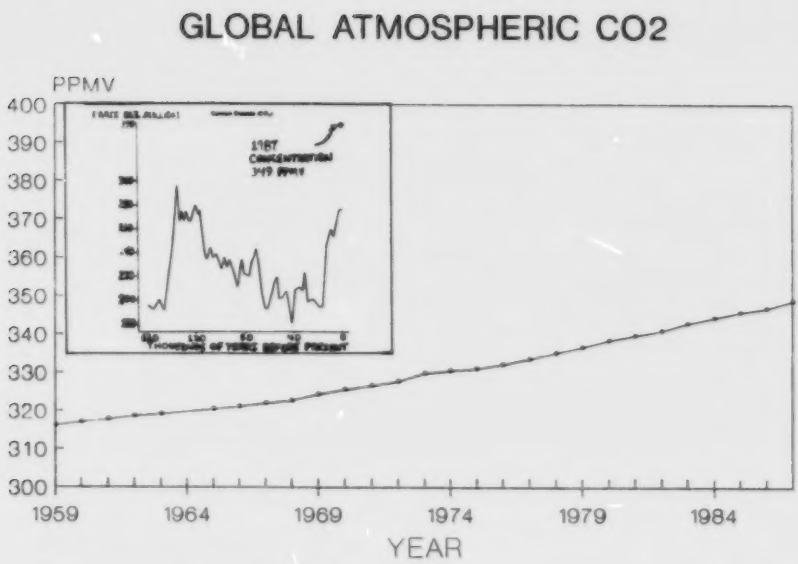

FIGURE 7. EVOLUTION OF THE ATMOSPHERIC CONCENTRATION OF CARBON DIOXIDE DURING THE LAST 160 000 YEARS (INSET) AND DURING CONTEMPORARY TIMES (MAIN GRAPH). PAST MEASUREMENTS WERE CONDUCTED ON AIR SAMPLES TRAPPED IN ANTARCTIC ICE CORES. PRESENT MEASUREMENTS ARE REPRESENTED BY THE DOTS ON THE MAIN GRAPH [REFERENCE 12].

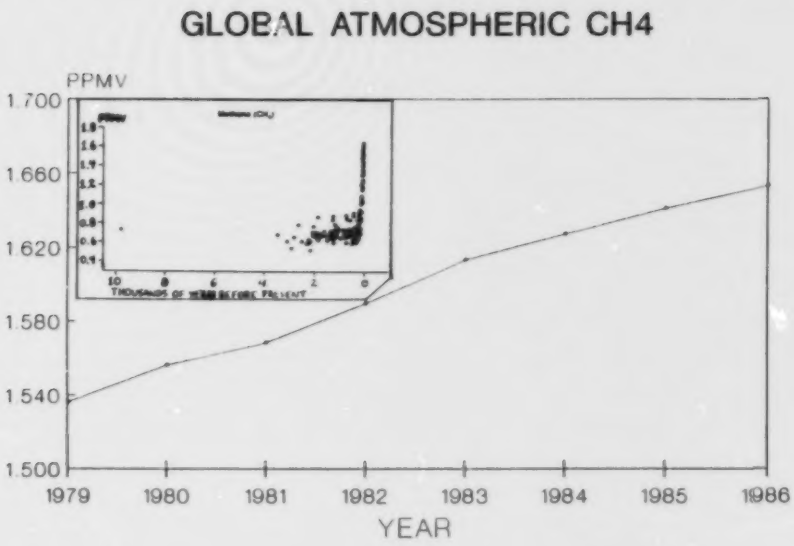

FIGURE 8. EVOLUTION OF THE ATMOSPHERIC CONCENTRATION OF METHANE DURING THE LAST 10 000 YEARS (INSET) AND DURING PRESENT TIMES (DOTS ON MAIN GRAPH). THE PAST CONCENTRATIONS WERE OBTAINED FROM ANALYSIS OF AIR SAMPLES TRAPPED IN POLAR ICE CORES. PRESENT DATA ARE DIRECT ATMOSPHERIC MEASUREMENTS [REFERENCE 12].

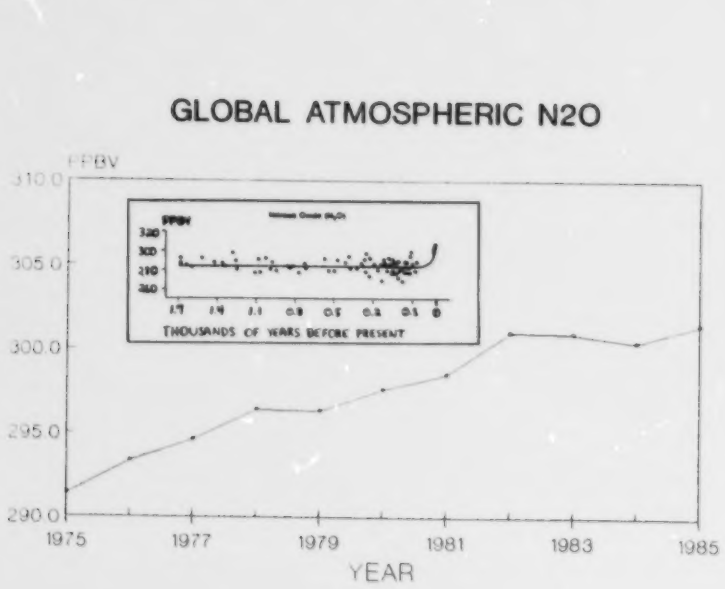

FIGURE 9. EVOLUTION OF THE GLOBAL ATMOSPHERIC CONCENTRATION OF NITROUS OXIDE DURING THE PAST (INSET) AND IN THE PRESENT (DOTS ON MAIN GRAPH). THE TIME SCALE IN THE INSET IS IN CALENDAR YEARS. THE DOTS ON THE MAIN GRAPH ARE RECENT MEASUREMENTS ON AIR SAMPLES [REFERENCE 12].

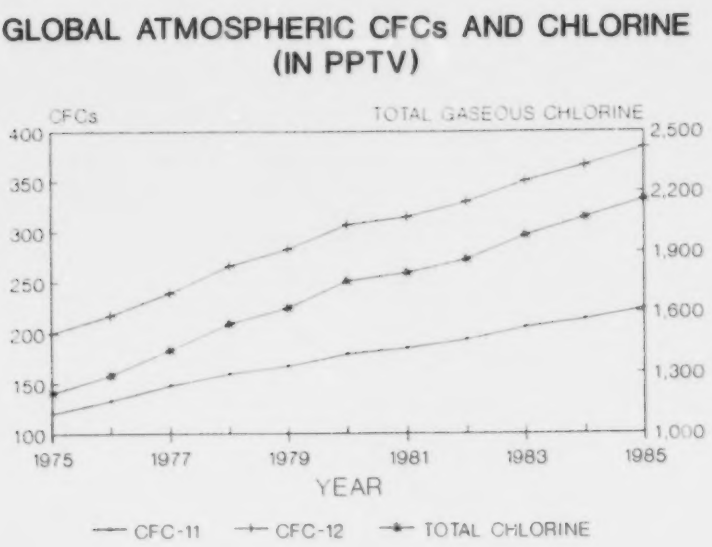

FIGURE 10. EVOLUTION OF THE CURRENT ATMOSPHERIC CONCENTRATIONS OF THE TWO MOST RADIATIVELY ACTIVE CHLOROFLUOROCARBONS: CFC-11 (DOTS) AND CFC-12 (CROSSES). THE THIRD CURVE (ASTERISKS) REFERS TO THE TOTAL GASEOUS CHLORINE SUPPLIED BY ALL THE CFCs. THE VERTICAL SCALE ON THE LEFT APPLIES TO THE ACTUAL CFC CONCENTRATIONS; THE VERTICAL SCALE ON THE RIGHT APPLIES TO THE TOTAL GASEOUS CHLORINE. THE PRESENT RATES OF INCREASE OF THE TWO PRINCIPAL CFCs WILL PROBABLY BE ALTERED BY ADHERENCE TO THE MONTREAL PROTOCOL. THE TIME REQUIRED TO REDUCE CFCs AND TOTAL CHLORINE WILL BE CONSIDERABLE BECAUSE OF THE LONG RESIDENCE TIMES OF CFCS IN THE ATMOSPHERE [REFERENCES 12 & 13].

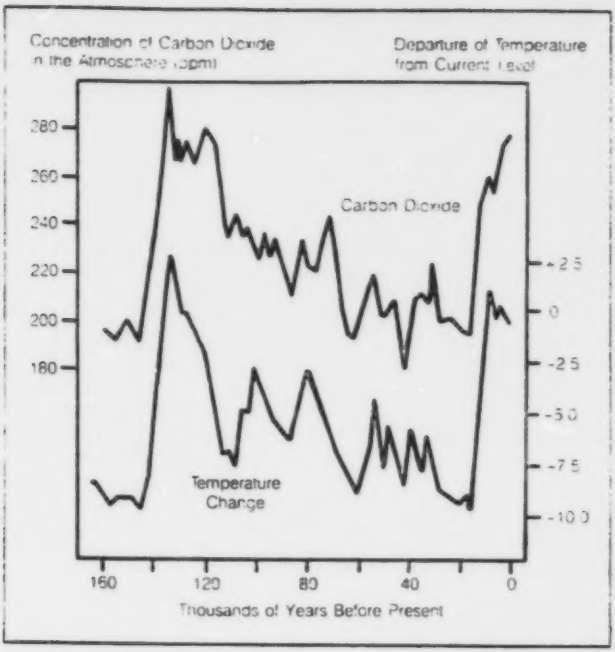

FIGURE 11. COVARIATION OF CARBON DIOXIDE CONCENTRATIONS AND RELATIVE GLOBAL TEMPERATURE CHANGE OVER THE LAST 160,000 YEARS, AS EVIDENCED IN AN ANTARCTIC ICE CORE. THE CO_2 WAS MEASURED IN AIR SAMPLES TRAPPED AT DIFFERENT LEVELS IN THE CORE. RELATIVE TEMPERATURE CHANGES ARE BASED ON THE DEUTERIUM (HEAVY WATER) CONTENT OF ICE TRAPPING THE AIR SAMPLES. THE RESOLUTION OF THE MEASUREMENTS FOR THE CURRENT DECADE IS POOR BECAUSE OF THE TIME REQUIRED FOR PRESENT DAY SNOW AND AIR TO BE PERMENANTLY ADDED TO THE ICE SHEET [REFERENCE 12].

the different environmental sources, sinks and pathways that determine their fate.

4. THE REGULATION OF GLOBAL CLIMATE

The Earth can be described as an enormous differential heat engine fueled by solar radiation. Because the axis of rotation is tilted with respect to the orbital plane, the amount of incoming radiation is not equal at all latitudes. This results in a temperature difference between the equator and the poles which drives atmospheric and oceanic circulation. Since the oceans have a much greater heat capacity and much slower circulation time than the atmosphere, the oceans tend to "buffer" rapid global temperature change, or at least to delay responses. The land masses and the biosphere itself also play significant roles in regulating climate, such that a very complex set of interactions has to be understood in order to predict how changes in environmental conditions can modify the climate.

The geological record contains numerous indications that the Earth's climate has undergone significant changes in the past. Over the last 130 million years, there has been a cooling trend in deep ocean water temperatures as reconstructed from measurements of oxygen isotope ratios in marine sediment cores (Figure 12a). This is not a perfect measurement of the mean global air temperature because deep ocean water is colder than the mean atmospheric temperature. But it does reflect a long-term trend in climate. However, this same oxygen isotope record shows alternating cold and warm temperatures beginning about 2.5 million years ago (Figure 12b). This shorter-term behaviour has been linked to cyclical changes in the Earth's orbital parameters that result in variations of incident solar energy at different latitudes. Longer periods of cool or cold climate are interrupted by generally shorter episodes of warm climate at intervals of 100 000, 41 000 and 22 000 years. During the last million years, the mean global temperatures during the coldest parts of the major ice ages was about 5°C colder than today. Shifts as small as 1°C to 2°C of the mean global temperature are enough to affect human populations around the world. The Norse colonization of Greenland occurred during a warm interval preceding the 13th century (Figure 12c). The cooler period between 1250 A.D. and 1450 A.D. ended settlement in Greenland and persisted throughout Europe until about 1850 A.D. This "Little Ice Age" had widespread effects on agricultural crops which have been well documented in the historical records of the time.

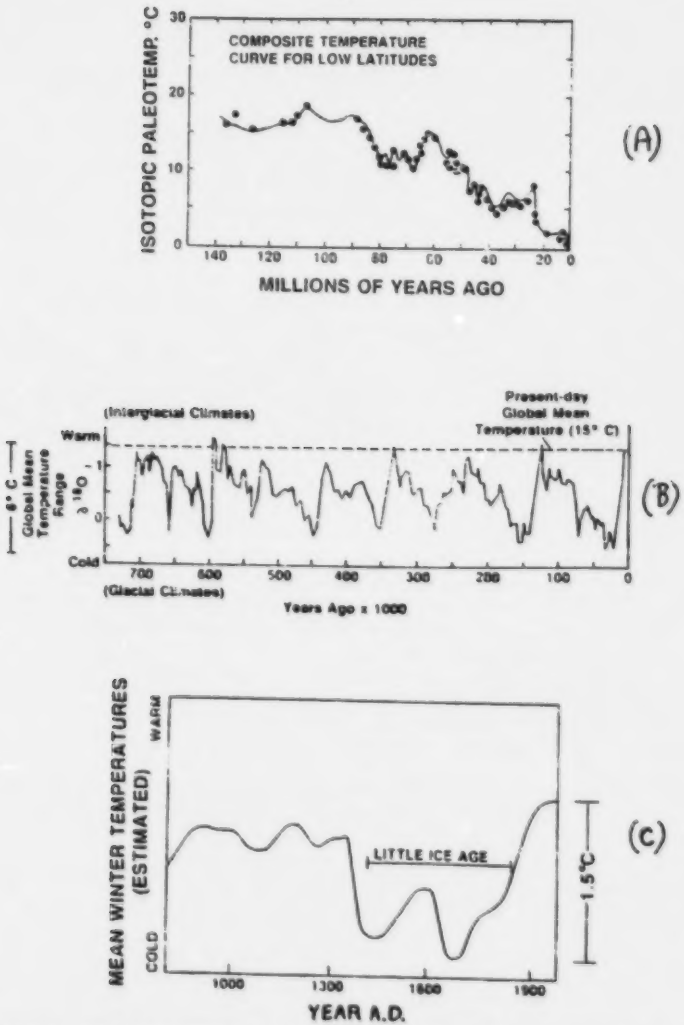

FIGURE 12. EVOLUTION OF THE MEAN GLOBAL TEMPERATURE AS RECONSTRUCTED FROM OXYGEN ISOTOPE RATIOS IN MARINE SEDIMENTS (A, B) AND HISTORIC NON-INSTRUMENTAL RECORDS (C). CURVE A REPRESENTS GLOBAL DEEP OCEAN WATER TEMPERATURES. CURVE B REFLECTS RELATIVE TEMPERATURE CHANGES OF OCEANIC SURFACE WATERS AND THE CHANGES IN GLOBAL ICE VOLUME; THE ATMOSPHERIC TEMPERATURE SCALE HAS BEEN ADDED FOR PURPOSES OF COMPARISON. CURVE C REFERS TO RELATIVE TEMPERATURE CHANGES FOR EASTERN EUROPE [REFERENCE 14].

5. THE ATMOSPHERE AND THE GLOBAL CARBON CYCLE

All matter and energy circulates throughout the environment so that an equilibrium can be established between the atmosphere, the lithosphere, the hydrosphere and the biosphere. Changes in concentrations of a given element or its compounds in any one of these compartments indicate that this equilibrium has been upset. The rapid increase of several atmospheric trace gases over the last few decades (Figures 7 to 10) is a symptom of a global environmental shift. The presence of CFCs throughout the global atmosphere demonstrates that man-made emissions are distributed on a global scale and could play a significant role in these changes.

The concentration of carbon dioxide in the atmosphere is a reflection of the processes taking place within the global carbon cycle. Some of these processes have been occurring very slowly over millions or billions of years (weathering of carbonate and silicate rocks, carbonate formation in the oceans, mantle outgassing). Others are relatively rapid biogeochemical processes that occur over days to years (photosynthesis, respiration, combustion of biomass and fossil fuels). Each of these processes has built up reservoirs of carbon (Table 3). The carbon cycle becomes unbalanced when the contents of a reservoir are introduced into the global atmosphere faster than they can be removed by the land, the oceans and the biomass. This imbalance results in a greater CO_2 concentration in the atmosphere. The combustion of fossil fuels gives Man the unique power to reintroduce quickly into the environment a reservoir of carbon that is much larger than what is routinely exchanged between the atmosphere and the biomass (Table 3, Figure 13). Present fossil fuel combustion releases about 5 billion tonnes of carbon to the global atmosphere every year (Figure 13) which had been previously locked up. The release of carbon to the atmosphere from fossil fuel combustion began to surpass the net flux from terrestrial systems sometime between 1940 and 1960. Emissions are calculated from records of fuel production published by the United Nations; they are thought to be known within 6% since 1950, and within 13% for the years between 1860 and 1950.

The best estimates of present day photosynthesis on land and in the oceans indicate that plant life is not removing all the carbon released by fossil fuel combustion. Furthermore, deforestation is decreasing global photosynthetic capacity by the net removal of trees. Clearing forests by burning, which is especially common in the Tropics, aggravates the problem because of rapid carbon dioxide release to the atmosphere (and furthermore, the energy that this could produce is not even harnessed). The purposeful burning of fuelwood and charcoal is estimated to produce about 10% of the CO_2 released from the combustion of fossil fuels. All told, these changes in land use prevent the removal of some 1.8 billion tonnes of carbon from the atmosphere (range: 0.4 to 2.5). Human activities represent a significant

fraction of the global emissions of several other important greenhouse gases; most of these human emissions are linked to the production and consumption of energy (Table 4).

TABLE 3. ABSOLUTE AND RELATIVE SIZES OF THE PRINCIPAL GLOBAL RESERVOIRS OF CARBON. A GIGATONNE IS EQUAL TO ONE BILLION METRIC TONNES [REFERENCE 15].

Reservoir	Carbon mass (Gigatonnes)	Carbon mass relative to life
Calcium carbonate (mostly in sedimentary rocks)	35×10^6	62 500
Ca-Mg carbonate (mostly in sedimentary rocks)	25×10^6	44 600
Sedimentary organic matter (as kerogen)	15×10^6	26 800
Oceanic dissolved bicarbonate and carbonate	42 000	75
Recoverable fossil fuels (coal and oil)	4 000	7.1
Dead surficial carbon (humus, caliche, etc.)	3 000	5.4
Atmospheric carbon dioxide	720	1.3
All life (plants and animals)	560	1.0
Human biomass	3	0.006

TABLE 4. HUMAN CONTRIBUTION TO THE YEARLY GLOBAL EMISSIONS OF THE FIVE MOST IMPORTANT RADIATIVELY ACTIVE GASES, AND THE FRACTION OF THOSE MAN-MADE EMISSIONS RELATED TO THE PRODUCTION AND CONSUMPTION OF ENERGY [REFERENCES 6 & 9].

Gas	Man-made contribution to global total	Man-made fraction related to energy
CO_2	3 ± 1 %	80 ± 20 %
CH_4	20 ± 10 %	32 ± 16 %
N_2O	28 ± 10 %	80 ± 20 %
$CFCl_3$	100 %	20 ± 10 %
CF_2Cl_2	100 %	5 ± 3 %

At present, only about half of the carbon released to the atmosphere from fossil fuel combustion, or roughly 2.5 billion tonnes, is being removed from the atmosphere. The oceans are the most likely sink. Carbon dioxide is chemically dissolved in surface ocean waters as well as taken up by the plankton. The gradual sinking of surface waters and the sedimentation of dead organic matter removes a portion of this carbon to the ocean depths and eventually to the sediments (Figure 14). The ability of the oceans to remove excess CO_2 from the atmosphere is tempered by their rate of circulation. It is further reduced by the chemistry of carbon in sea water because

only about 10% of the surplus CO_2 is required to reach an equilibrium of partial pressures across the air-water interface. This percentage is called the Revelle Factor and it varies between 7% and 11% according to water temperature and alkalinity. As a result of these physical and chemical mechanisms, the mixed surface layer (0-70 m) takes about a year to reach equilibrium with the atmosphere. The thermocline layer (70-1000 m) reaches equilibrium with the atmosphere only after several decades. The deep waters (>1000 m) equilibrate with the atmosphere over centuries. It takes thousands of years for the sediments to reach an equilibrium with the atmosphere. As for the calcium ions released into the ocean after the reaction between CO_2 and calcite ($CaCO_3$) in the sediments, equilibrium is reached only after several tens of thousands of years.

Atmospheric CO_2 content is the most reliable measurement in the global carbon budget. Atmospheric circulation is sufficiently rapid to produce a homogeneous mixture of gases, so that it is easier to collect samples that are representative of the whole. The chemical composition of the oceans is more variable: chemically distinct water masses are persistent features of the ocean. The considerable costs and logistical difficulties of oceanographic research hinder a detailed and comprehensive knowledge of the role of the oceans in the global carbon cycle. The estimates of oceanic uptake of excess atmospheric CO_2 need to be improved before we can understand how the seas will react to projected increases of greenhouse gases in the atmosphere. International projects such as JGOFS (Joint Global Ocean Flux Study) are trying to plug the gaps in our knowledge, but many more undertakings of this scope are needed.

6. GLOBAL TEMPERATURE CHANGE AND ITS PREDICTION

The temperature of the global atmosphere has been measured and studied for a longer period of time than its radiative gas content. Reliable instrumental measurements go back roughly 100 years for temperature, but only 31 years at the most for radiatively active gases. Air samples trapped in ice sheets and glaciers can extend temperature and gas measurements back to 160,000 years before present, while geological proxy climate indicators, such as stable isotope ratios and distinctive features caused by glaciation, provide relative temperature changes going back several hundred million years.

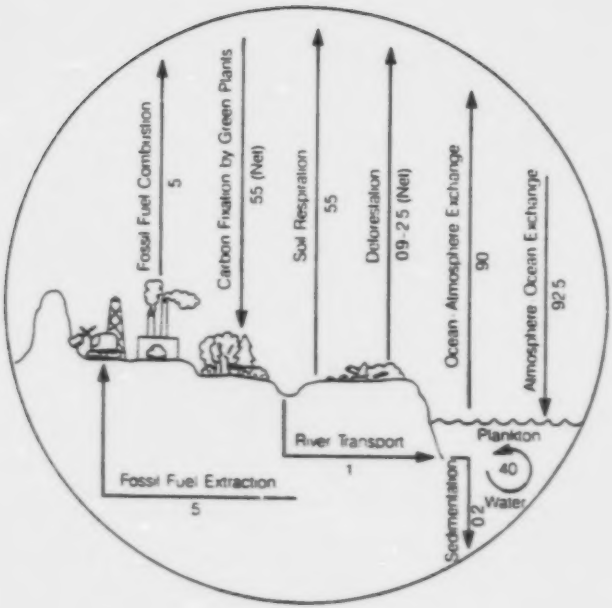

FIGURE 13. SCHEMATIC REPRESENTATION OF THE SHORT-TERM FLUXES GOVERNING THE GLOBAL CARBON CYCLE. FIGURES ARE IN BILLION OF METRIC TONNES (GIGATONNES) OF CARBON, ACCORDING TO BEST AVAILABLE ESTIMATES. ATMOSPHERIC CARBON IS ALMOST ENTIRELY PRESENT AS CARBON DIOXIDE [REFERENCE 16].

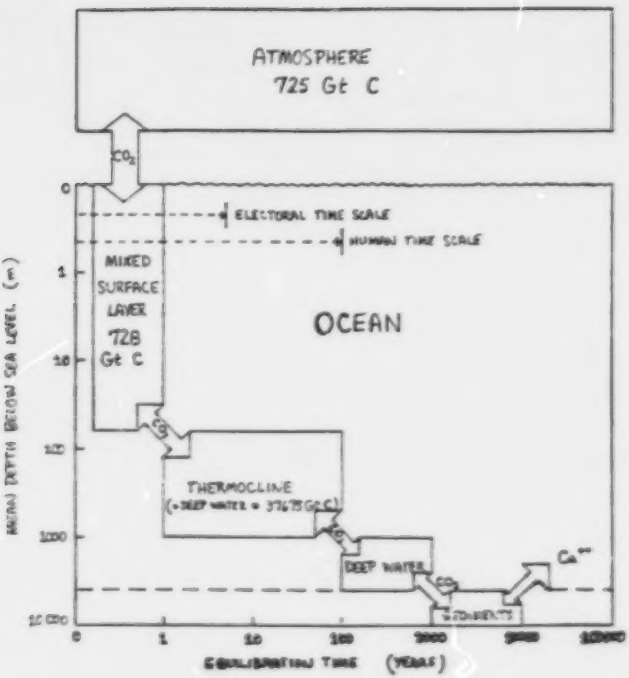

FIGURE 14. SCHEMATIC REPRESENTATION OF THE EQUILIBRATION TIMES BETWEEN THE ATMOSPHERE AND THE PRINCIPAL OCEAN LAYERS WITH RESPECT TO CO_2. THE LAYERS ARE REPRESENTED TO THEIR RESPECTIVE AVERAGE DEPTHS: 70 METRES FOR THE MIXED SURFACE LAYER, 1000 METRES FOR THE THERMOCLINE, AND 3800 METRES FOR DEEP OCEAN WATER WHICH CORRESPONDS TO THE AVERAGE DEPTH OF THE WORLD'S OCEANS [REFERENCE 17]. TWO REPRESENTATIVE TIME SCALES THAT ARE EASILY PERCEPTIBLE BY HUMANS HAVE BEEN SUPERIMPOSED (AS DEFINED IN FIGURE 3).

Most scientists agree that the average temperature of the Earth's surface has increased by 0.5°C to 0.7°C since the turn of the century (Figure 15). Moreover, last year was the warmest on record and this decade has known the six hottest years ever measured directly (in order: 1988, 1987, 1983, 1981, 1980 and 1986). These results are the outcome of millions of temperature observations compiled during the year over land and sea. Although some doubts have been raised as to biases caused by the urban heat island effect, this applies only to a small part of the total. Applying the appropriate corrections still suggests a global warming of 0.5°C since 1880. This warming has not been uniform throughout our century: the period 1940 to 1960 was slightly cooler than the period since. The overall trend however is to warmer average temperatures, as this decade clearly illustrates to date. Are we seeing the effects of our atmospheric emissions on the Earth's climate or merely undergoing a temporary natural variation? Climatologists cannot answer yet with the absolute certainty demanded in several quarters, but they are trying to model the complex interactions that determine climate.

The science of climate prediction is attempting to reconcile two distinct methodologies or approaches to the problem. The first attempts to predict future climate conditions by analogy with similar situations that have left their trace in the geological record. It requires interpretation of a variety of proxy climate indicators: isotope ratios, fossil pollen associations, sediment composition and structure, etc. Some historical information can also provide clues to past climatic variations. The second approach attempts to predict future climate through the manipulation of General Circulation Models (GCMs). These are very complex sets of simultaneous differential equations describing the numerous interactions and feedback mechanisms believed to determine climate. They are recognized as approximations of the real world. Despite their relative simplicity in comparison to Nature, they require supercomputers to run. A typical three-dimensional GCM will need weeks or months of computer time to perform all the necessary calculations leading to a global temperature prediction for a given increase in the concentration of CO_2.

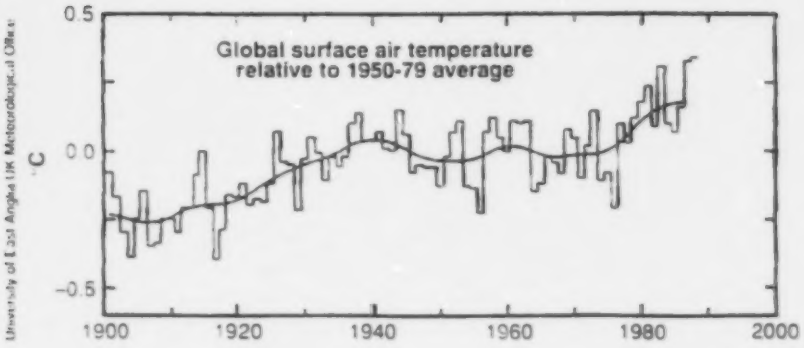

FIGURE 15. CHANGES IN THE MEAN GLOBAL SURFACE AIR TEMPERATURE RECORDED BETWEEN 1900 AND 1988. THE BASELINE IS THE 1950 TO 1979 AVERAGE (ZERO ON THE VERTICAL AXIS). THE SOLID LINE IS THE FIVE-YEAR RUNNING MEAN, AND THE PEAKS AND VALLEYS ARE YEARLY DEPARTURES FROM THE FIVE YEAR MEAN. THE DATA CLEARLY INDICATE THAT THIS DECADE HAS BEEN WARMER TO DATE THAN AT ANY PREVIOUS TIME SINCE RELIABLE MEASUREMENTS HAVE BEEN PERFORMED [REFERENCE 18].

The standard procedure is to initiate the GCM simulation by doubling the CO_2 concentration and allowing the model to calculate the resulting equilibrium temperature. The CO_2 doubling times are determined by assumptions of fossil fuel consumption, deforestation rate, land use changes and so forth, that are external to the model. An increase in the annual fossil fuel consumption rate will typically hasten the doubling of atmospheric CO_2, thus determining how soon the predicted temperature increase will occur (Table 5).

There are five principal General Circulation Models, named after the institutions that developed them:

- United Kingdom Meteorological Office (UKMO);
- Goddard Institute for Space Studies (GISS);
- Geophysical Fluid Dynamics Laboratory (GFDL);
- National Center for Atmospheric Research (NCAR); and
- Oregon State University (OSU).

A sixth one has just been developed by the Atmospheric Environment Service of Canada and has been used to simulate the dispersion of various pollutants such as the emissions from the Chernobyl nuclear accident.

TABLE 5. THE EFFECT OF ANNUAL GROWTH RATE OF FOSSIL FUEL CONSUMPTION ON THE DOUBLING TIME OF ATMOSPHERIC CO_2 FROM 1985 LEVELS [REFERENCE 19].

Annual rate	Doubling time in years	Year of doubling from 1980 value
Constant (from 1975)	180	2165
1.0 %	70	2055
2.0	35	2020
4.0	17.5	2003

All these models predict that a doubling of atmospheric CO_2 will increase the global average temperature, but the amount of change differs from one to the other (Table 6). The differences between these predictions may appear to be small, but they are important given the magnitude of the system involved.

TABLE 6. EFFECT OF A DOUBLING OF ATMOSPHERIC CO_2 CONCENTRATION ON THE INCREASE OF GLOBAL TEMPERATURE, ACCORDING TO THE FIVE PRINCIPAL GLOBAL CIRCULATION MODELS [REFERENCE 20].

Model	Temperature increase
UKMO	5.2 °C
GISS	4.2 °C
GFDL	4.0 °C
NCAR	4.0 °C *
OSU	2.8 °C

* Updated from previous prediction of 3.5 °C

General circulation models suffer from a number of theoretical and practical problems that elicit cautious interpretation of their results. Although they are reasonably good at predicting present global seasonal patterns of temperature when tested against actual measurements, they cannot resolve patterns on a scale smaller than their typical grid size of several hundred kilometres to the side. (GCMs divide the Earth into grid squares and perform calculations for each before piecing them together to obtain a global picture). The sheer number of calculations necessary for grid squares of tens of kilometres to the side (useful for regional forecasts) defies present computing technology.

The large grid size also prevents the realistic modelling of clouds and their effects on the atmospheric heat budget. Clouds are typically smaller than a standard grid square, which probably means that their effects would have to be simulated by different equations or parameters in each square, a messy computational problem. There is no scientific consensus on how clouds will act: they would probably increase in a warmer climate because of greater evapotranspiration, but this could bring about more reflection of incoming radiation (a cooling effect) or increased interception of outgoing radiation (a warming effect). When the GCMs are run without their respective equations for cloud effects, their temperature predictions agree quite closely. When the cloud feedbacks are restored, the models differ by as much as a factor of three.

The relatively greater uncertainty surrounding ocean processes as compared to atmospheric ones is another recognized shortcoming of the GCMs in use today. The resulting equations expressing ocean-atmosphere interactions are far from satisfactory. Further research is vital to improving our knowledge in this area.

Perhaps the greatest uncertainty surrounding the General Circulation Models is that their predictions can never be proved conclusively; they can only be verified by circumstantial evidence, such as their ability to simulate past climates or the seasonal cycle. Stephen H. Schneider, one of the foremost climate modellers,

expressed this problem lucidly in a recent article [REFERENCE 8, p.80]:

> " Climate models do not yield definitive forecasts of what the future will bring; they provide only a dirty crystal ball in which a range of plausible fortunes can be glimpsed. They thereby pose a dilemma: we are forced to decide how long to keep cleaning the glass before acting on what we think we see inside.
> The dilemma is perhaps less acute in the case of nuclear war, whose consequences would in any event be catastrophic, than it is in the case of atmospheric pollution. [Editor's note: the author is referring to the use of models in predicting the environmental effects of nuclear war, the "nuclear winter" hypothesis] At present we are altering our environment faster than we can understand the resulting climatic changes. If the trend does not stop, we shall eventually either verify or disprove the climate models - by means of a real, global experiment whose consequences we shall not escape."

Throughout its existence, the human species has been the victim, beneficiary and observer of the Earth's climate. What it knows about the effects of climatic variations on its activities is being combined with the predictions of its "dirty crystal ball" so as to anticipate the major impacts of our changing atmosphere.

7. SOME MAJOR CONSEQUENCES OF CLIMATIC WARMING

On a global level, the two most obvious consequences of global warming are an increase of sea level and changes in the distribution of rainfall. Both of these phenomena can have profound effects on a multitude of human activities.

As the global average temperature increases, sea level can be expected to rise because of the thermal expansion of surface waters and the accelerated melting of the continental ice sheets (Figure 16). Since the beginning of this century, the global sea level has risen at an average rate of 14 $\pm$ 5 centimetres per century. Given the modest but significant correlation between sea level and global mean surface temperature observed to date, a warming of 1.5 to 5.5°C would lead to a rise of 25 to 165 cm by the time of CO_2 doubling. According to this scenario, the Greenland ice sheet would decrease. It is also surmised that increased ocean surface temperatures would lead to a collapse of the West Antarctic ice sheet if the global warming were to be from 3 to 4°C. But another hypothesis proposes that there would be increased precipitation over the Antarctic and a slow increase of ice volume, thus outweighing the effects of increased ocean temperatures. A collapse of the Antarctic ice sheet would increase sea level by roughly 5 metres, but this would most likely occur over several hundred years.

Rising sea levels would have numerous consequences on heavily populated low-lying coastline nations such as Bangladesh, where thousands to millions of people are within reach of monsoon floods. Higher seas not only encroach on coastal lands, they also allow storm surges to penetrate further inland. In addition to accelerated erosion, there is the added possibility of salt water intrusion in groundwater aquifers, especially if they are being pumped faster than their renewal rate.

In Canada as well as in other coastal countries, a one metre rise in sea level would cause major flooding in port and recreational facilities, storm sewers, roads and prime real estate. Greater intrusions of salt water in estuaries might alter the habitat of commercial and sport fisheries.

The rate of rise cannot be accurately predicted yet, but the faster it is, the more expensive it will be to protect the numerous inhabitants and economic facilities that congregate near shorelines around the world.

While climatic warming can expose us to greater quantities of salt water on the one hand, at least one GCM is predicting, on the other hand, major shortages of fresh water in several parts of the world (Figure 17). It is predicting increased drought at mid to high latitudes above the Equator, and especially in the continental interior. A doubling of CO_2 might result in a soil moisture decrease of up to 50% in the heavily cultivated Canadian Prairies and American Midwest. Tropical latitudes could expect more rainfall, especially in Monsoon areas. It is not possible at present to determine if differences in regional forecasts made by the GCMs are due to a shortcoming of the modelling approach in general or errors specific to each particular model.

The consequences of severe drought in North American agricultural areas would be very serious. Several major crops, such as corn and rapeseed, require substantial irrigation that would be difficult to provide in times of repeated drought. The prices of foodstuffs would most certainly increase dramatically in response to crop failures. It will not be easy to forecast crop yields in the light of uncertain climatic predictions, but most models are suggesting that significant drought is a serious possible outcome of global warming.

An alteration of climate implies an alteration of habitat conditions for all of the Earth's living species, including those of economic value to Mankind. Trees would be quite vulnerable to rapid temperature changes

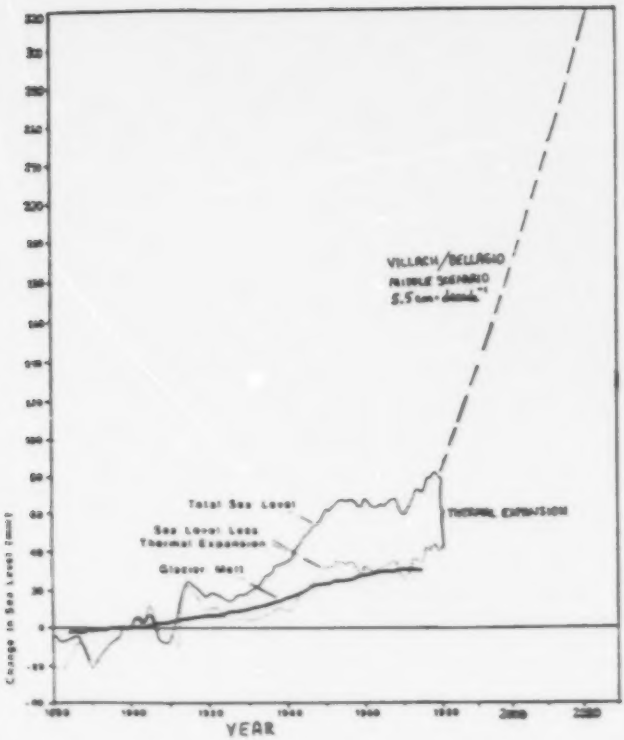

FIGURE 16. INCREASE OF GLOBAL SEA LEVEL SINCE 1880. THERMAL EXPANSION REPRESENTS THE MAJOR CONTRIBUTION TO THE TOTAL OBSERVED RISE. THE DASHED LINE REPRESENTS THE MID-RANGE SCENARIO THAT AROSE FROM EXPERT DISCUSSIONS AT THE VILLACH AND BELLAGIO CONFERENCES ON THE ENVIRONMENTAL EFFECTS OF PREDICTED GLOBAL WARMING [REFERENCES 21 & 22].

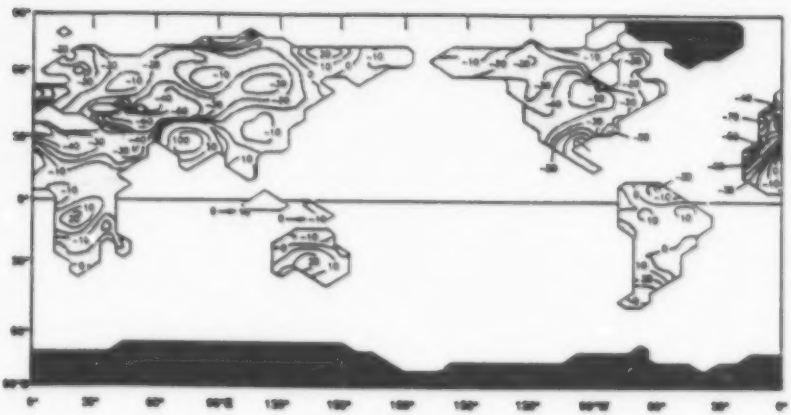

FIGURE 17. PREDICTED CHANGES OF SOIL MOISTURE IN RESPONSE TO A DOUBLING OF ATMOSPHERIC CO_2. THE CHANGES ARE EXPRESSED AS PERCENTAGE CHANGE RELATIVE TO PRESENT SOIL MOISTURE CONTENT. NEGATIVE NUMBERS REPRESENT NET LOSSES AND POSITIVE NUMBERS STAND FOR NET GAINS. THE SEVEREST LOSSES ARE CONCENTRATED IN THE INTERIOR OF ASIA AND NORTH AMERICA AT MID LATITUDES. THESE PREDICTIONS ARE BASED ON THE GFDL MODEL [REFERENCE 23].

within their present ranges of distribution. Each 1°C rise in temperature over a given area of North America translates into a geographical range shift of about 100 to 150 Km northwards. That means that species will have to change their patterns of distribution. The fossil record shows that this has occurred during past episodes of climatic change. Spruce, for example, is capable of spreading 200 Km a century as witnessed by its migration into Canada after the last ice age about 9,000 years ago. Beginning about 15,000 years ago, most North American tree species migrated northwards at a rate between 10 and 45 Km per century. However, the anticipated rate of global warming according to GCM simulations is much greater than in the past. Beech, for example, would have to migrate 40 times faster this time than after the last ice age. This raises doubts about the ability of our forests to adapt to the projected change of climate. The consequences would be very serious for a country like Canada that derives a large part of its wealth from forest products.

8. CONCLUSION

Scientific investigation of climatic change and possible human involvement has provided some fascinating and sobering insights into the dependence of Mankind upon his environment. Faced with actual measurements that span only a very short interval in the history of this planet, with an indirect glimpse of past conditions, and with incomplete mathematical simulations upon which to plot our environmental future, we are tempted to minimize the seriousness of the global change issue or to profess our inability to respond. Society is facing a choice between taking action now against an outcome that might not materialize, or invoking uncertainty to spare itself the difficulty of taking action now, only to find out too late that the unspeakable has occurred.

The questions are appearing much more quickly than the answers. Work must continue to provide enough understanding to improve our predictions while charting a course for responsible action. But scientific knowledge alone cannot obviate the need to make wise choices. As the environmental stakes broaden to encompass the entire planet, we must recognize our power to alter our environment and the responsibilities that accompany such an attribute, lest we jeopardize our future.

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DIOXINS, PCBs AND THE CHLORINE INDUSTRY

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Greenpeace is an international environmental organization with offices in more than 20 countries. Greenpeace works on many issues which deserve to be addressed at a symposium such as this one. Much of our toxics related work, for example, has focused on the disposal of toxic wastes, e.g. on incineration and direct discharges into the environment or on the international waste trade. The overall goal is to eliminate the sources of these toxic wastes by introducing clean production methods or or by substituting the products.

This paper will use the highly publicized issue of chlorinated dibenzo-p-dioxins, dibenzofurans and biphenyls as an example of how governments typically deal with the toxic waste crisis and how environmentalists would like to see their governments deal with this crisis.

Polychlorinated dibenzo-p-dioxins and their chemical relatives, the dibenzofurans, are not only extremely toxic but also extremely bio-accumulative. PCBs are related in that they work through the same mechanisms in the organism, i.e. through the same protein receptor, but are less potent than the dioxins and furans.

Much research has focused on these chemicals to find out exactly how toxic they are. For example, in 1985 at the 5th Int'l Dioxin Symposium, it was estimated that, by then, more than US$ 1 billion had been spent on dioxin research alone [1]. It is probably fair to say that we are closer to the US$ 2 billion mark today.

Effects on the Environment

Research has established over and over again that the dioxin 2,3,7,8-TCDD is the most potent carcinogen tested on laboratory animals to date, and that it causes suppression of the immune system and reproductive failure.[2] Although less potent, the same effects are caused by PCBs. One must be clear that if dioxins and PCBs are as toxic as this to laboratory animals, they will be as toxic to wildlife.

The Baltic gray seal is a case in point: in the mid-seventies it was found that only 20 percent of the mature female gray seals were fertile.[3] This is commonly attributed to the high levels of PCBs in the Baltic food chain. Interestingly, when seals are raised with a diet of less contaminated fish caught outside the Baltic, the seals are able to reproduce.

Infertility is not the only effect linked to PCBs in the seals' diet: over 75% of the seals found dead in recent years have been found to have intestinal ulcers and kidney damage. Roughly half the female gray seals also had uterine tumors. Often, even the living seals display these same diseases.

In Canada, one need only look at the plight of the St. Lawrence Beluga whales, whose population has declined dramatically over the years, due to chemical pollution. The Belugas are so badly contaminated with PCBs that, once they die, their bodies are declared hazardous wastes.

Yet even such blatant examples of what these chemicals can do to our wildlife have not convinced our governments that it is high time to halt the continued release of these and other related chemicals into the environment. Instead, governments reassure us that there is no conclusive evidence yet, that these same chemicals cause health problems in humans.

Human Health Effects

Most of the discussion on human health effects has focused on whether dioxin is a human carcinogen, while at the same time other at least as important health effects, such as suppression of the immune system or reproductive failure, are given no attention.

It is also extremely discouraging to see that this politically so sensitive discussion, on whether dioxin causes cancer in humans or not, has not been without bias, to put it politely.

One of the best analyzed groups of exposed humans are chemical workers who produced the herbicide 2,4,5-T. A W-German producer, BASF, experienced an explosion in 1953, exposing workers to relatively high doses of the dioxin 2,3,7,8-TCDD. Many of the these workers subsequently suffered from chloracne.

At the 1989 international symposium on dioxin and its toxic effects, W-German scientist P. Rohleder presented a re-analysis of these exposed BASF workers. He not only found significantly elevated levels of respiratory cancer and cancer of the digestive system, but he also found that earlier studies, paid for by the BASF itself, were fraudulent: non-exposed workers had been deliberately added to the 'exposed' cohort, and truly exposed workers, some of whom were displaying chloracne, had been deliberately excluded from the study.(4)

Evidence that PCBs may be carcinogenic in humans is mounting as well. A cancer study by the Cincinnati National Institute for Occupational Safety and Health found that Westinghouse workers in Bloomington, Indiana, who were occupationally exposed to PCBs, experienced a more than two-fold increase in mortality from brain cancer and a four-fold increase in deaths from skin cancer.(5)

Dioxins in Human Milk

Perhaps most disturbing of all is the fact that over the last few decades, human milk in the Western World has become highly contaminated with dioxins and other chlorinated toxins.

An average breast-fed baby in industrialized countries already ingests up to 100 times more dioxin than the World Health Organization deems tolerable for a healthy adult.(6) The margin of safety, that is the difference between the levels of dioxin we expose our babies to and those that we know will cause adverse effects in laboratory animals,

is on the order of ten to non-existent. Babies in heavily contaminated areas are already exposed to dioxin levels that are certain to induce toxic effects in laboratory animals.

Aside from these dangerously high levels of dioxins and furans, mother's milk also contains other toxic chlorinated chemicals, such as PCBs, hexachlorobenzene, and polychloro-naphthalenes to name just a few. Yet no research has been carried out on the likely synergistic effects of these compounds, just as no research has ever been carried out on what harm these chemicals do to a baby's developing immune system.

Further, some scientists believe that exposure in utero from transplacental migration of these chlorinated chemicals may have important effects on brain development, and thus may be of even more concern than postnatal exposure through mother's milk.(7)

The Sources and Elimination Strategies

Given all these known facts about the toxicity and the increasing contamination or our environment and ourselves with dioxins, furans and PCBs, one can only conclude that it is absolutely essential to prevent any further build-up of these chemicals in the food chain. The first step must be the immediate elimination of all sources of these chemicals.

Fortunately, the OECD decided to outlaw commercial production of PCBs in its member countries as of 1989. The worry now is how to eliminate existing stock piles without releasing further PCBs into the environment by using unsafe disposal methods. As elaborated on below, incineration cannot be viewed as a safe destruction method, although many governments champion incineration as the best disposal method available.

Despite the halt of commercial production, PCBs may well continue to be synthesized and released into the environment as unwanted by-products in many chemical production and incineration processes, along with their chemical relatives dioxins and furans, as well as other chlorinated chemicals such as hexachlorobenzene or chloronapthalenes. This unwanted synthesis is due to the thermodynamical stability of all these compounds, and the fact that both production and incineration inevitably produce free chlorine radicals.

SOURCE	ELIMINATION STRATEGY
PRODUCTION OF ORGANOCHLORINES, e.g.:	
* chlorophenols and chlorobenzines	- ban production and use immediately
COMBUSTION OF ORGANOCHLORINES, e.g.:	
* car exhaust, leaded gas	- no organochlorine scavengers (use unleaded gas)
* municipal waste incinerators	- comprehensive recycling
* haz. waste incinerators	- waste reduction// elimination and use other destruction methods
* copper reclamation	- eliminate PVC coating
* steel recycling	- no chlorinated rubber/plastics to be used in car or machinery
USE OF CHLORINE GAS, e.g.:	
* pulp and paper industry	- less bleaching and bleaching with oxygen/H2O2
* zinc/magnesium smelters	- use chlorine free process

Box 1.

Box 1 lists major industrial sources of dioxin, and appropriate elimination strategies. It is obvious that the common denominator to every single one of these sources is modern society's use of chlorine and preoccupation with incineration.

Whenever organochlorines are produced, and even more so, whenever organochlorines are incinerated, dioxins will be formed. They will be released into the environment either directly into air and water, from the incinerators or the discharge pipes, or they will travel with the consumer products until their disposal.

Interestingly, elemental chlorine does not exist in Nature, and Nature does not produce organochlorines on a large scale either, with the exception of some very simple molecules, such as methylchloride or dichloromethane. Other more complex natural organochlorines are synthesized in a very small scale only.

All these industrial dioxin sources would be easy to eliminate if there were the political will. Chlorophenols, for example, are already banned in many European countries. Chlorophenols are a particularly heavy contributor to our growing dioxin contamination, both during the production process and due to the disposal of treated consumer products, e.g. the burning of treated leather, lumber or railway ties. Sweden actually experienced a decline of dioxin levels in human milk after banning both pentachlorophenol and chlorophenol-based herbicides.

Yet, both Canada and the United States actively resist such a ban, and chlorophenols are still widely used for wood protection and

preservation. In Canada, pentachlorophenol can even be bought over the counter.

When talking about production and use of chlorophenols, one must also mention the wide-spread use of pentachloro-thiophenol in the production of rubber tires. Thiophenols, too, will produce dioxins when incinerated. In the light of both the recent tire fire in Hagersville, and the growing desire to recycle old tires, it is clear that we need to phase out production and use of chloro- thiophenols as well.

Another very significant but completely avoidable source of dioxins and other stable chlorine compounds is municipal incinerators, which not only generate vast amounts of dioxin-laden ash but also emit dioxins into the atmosphere where they can be transported over long distances. The disposal of toxic incinerator ash has become a highly publicized problem since export schemes to Panama and other developing nations were exposed by Greenpeace.

Municipal incinerators should be eliminated for other environmental reasons as well: incinerators are not compatible with recycling schemes, since comprehensive recycling eliminates the cheap fuel incinerators rely upon to be economically viable, e.g. paper or plastics. Hospital incinerators, too, are major dioxin sources, due to the burning of disposable items made of polyvinyl-chloride (PVC).

Hazardous waste incinerators, too, emit toxic dioxins, furans and PCBs into the atmosphere, whenever burning chlorinated wastes. Experience has shown over and over again, that the successful small scale destruction of these very stable compounds in the laboratory cannot be repeated in large scale commercial incinerators. Instead, residents living near such commercial incinerators complain of health effects, and, as in the case of two ReChem incinerators in Great Britain, even point to birth defects in their children.

Chlorinated solvents make up a significant amount of the chlorinated wastes burned in hazardous waste incinerators. The Swedish government, for example, is now pushing for a phase-out of chlorinated solvents, due to the waste disposal problems they pose, but also due to the risks they pose to ground water supply, and their effects in the lower atmosphere.

Another very significant source of dioxins is copper reclamation. Copper wires are coated with PVC, and often even contain further organochlorine flame retardants. It would be so easy to replace this coating with other plastics and flame retardants that contain no chlorine, to facilitate recycling, yet both Canada and the USA failed to ever suggest such a change-over.

Many W-German cities, e.g. Bielefeld, Munich, Aachen and others, have now banned the use of PVC material in public buildings to protect the public and fire fighters from dioxin formed during house fires. The Danish government is actively pursuing a phase- out of all PVC articles, and is presently researching a feasible time-table.

Finally, the pulp and paper industry, certain branches of the metallurgical industry, as well as municipal sewage plants are significant sources of dioxins and related toxins due to their use of raw chlorine. Chlorine gas reacts with wood compounds or carbon electrodes, or various compounds in the sewage to form dioxins.

It is encouraging to see that the pulp and paper industry is moving towards cutting down on the amount of chlorine used for bleaching purposes, although there still is no will to work towards zero discharge as the ultimate goal.

Yet, metallurgical process as well as the sewage plants have completely escaped the attention of the Canadian and American government, even though alternative metallurgical process exist, and even though the chlorination of raw sewage does not eliminate the health hazard of such discharges, since chlorination does not kill off viruses.

The Politics - Whose Interests are at Stake?

Obviously, the elimination of man-made dioxin sources means eliminating a much larger portion of toxic chemicals from our environment. This would be a very positive move from an environmental point of view, because dioxins, despite their outstanding toxicity, are indeed only the tip of an iceberg of environmentally dangerous organochlorines.

But, when the entire organochlorine and even organohalogen production is being questioned, some very powerful interest groups will want to have a say. Much is at stake, both in terms of liability law suits and lost profits.

It would be very naive to think that the chlorine- and organochlorine-producing industry has had no influence on the colour of dioxin science. Other vested parties to name include the incineration lobby, the forest products industry and the metallurgical industry. Even defense departments are involved in the discussion, due to the use of Agent Orange in Vietnam and elsewhere.

The result: instead of devoting research efforts towards elimination of dioxin sources, such as finding alternative products or production technologies and safe methods of detoxifying existing wastes, the public is being deluged with attempts to linguistically detoxify dioxin, via media releases, information brochures and widely publicized risk assessments.

Risk assessments, in particular, can at best only be viewed as pseudo-scientific exercises, because they never take into account

* total exposure from all possible sources
* synergistic effects with other chemicals
* effects on the next generation, for example through contaminated human milk
* all possible health effects, rather than selected health effects only, e.g. certain forms of cancer.

Another diversion strategy by industry is to claim that dioxin is naturally occurring, i.e. that is is formed during forest fires or in wood stoves. None of the studies investigating these sources, however, has ever established whether or not man-made chlorinated chemicals were present on the wood or had been co- fired in the stove, e.g. herbicides, wood preservatives or paper products and plastics.

The theory of the naturally occurring dioxin was first introduced by Dow Chemical as the 'Trace Chemistry of Fire' theory.[8] This theory has since been convincingly disclaimed by at least three separate

studies which involved analysis of centuries old lake sediments or mummies. All three concluded that dioxin levels in the environment and in humans are intimately linked to modern industrialized society.[9,10,11]

Conclusions

Probably one of the largest challenges facing us in this century is to integrate our industry into Nature, that is to produce materials that are completely compatible with Nature, rather than trying to force Nature to become compatible with industry's products and wastes.

To Greenpeace, dioxin has become a symbol of whether we want to deal with our pollution problems and stop producing man-made chemicals on a large scale, or whether we will continue our self- destructive lifestyle.

More than enough research exists to prove that dioxin and related compounds are extremely toxic to wildlife, and that levels in our environment are rising. To wait for absolute conclusive proof that dioxins are deadly to humans, too, e.g. via contaminated human milk, is to wait until the point of no return, simply because such absolute proof can only be gained after irreversible damage is done. Instead, a new, preventive approach is needed. Many international fora, including UNEP, the Helsinki Commission as well as the Paris and Oslo Commission, have already embraced the concept of the Precautionary Principle.

This new concept of prevention is meant to replace the present concept of pollution control, which is based on the assumption that the environment can safely assimilate, and render harmless or dilute, a variety of contaminants.

In order to implement the Precautionary Principle, these international fora have targeted substances which are toxic, persistent, and bio-accumulative, with the goal of reducing, and eventually eliminating, theses substances at source.

The elimination of man-made dioxin sources would go hand-in-hand with the elimination of the much larger chemical group of organochlorines. But there are reasons to eliminate production and use of organochlorines, other than just to prevent dioxin formation.

Organochlorines, and as a matter of fact all organohalogens, are toxic to the environment in their own right, with chlorinated solvents irreversibly contaminating ground water supplies, chlorofluorocarbons depleting the ozone layer, and chlorinated and brominated pesticides causing reproductive failure in birds.

Some international fora have already blacklisted organochlorines or organohalogens. For example, the Annex to the 1974 Paris Convention, which covers marine pollution from land-based sources, has specifically listed organohalogen compounds as substances that should not be dumped into the marine environment.

Technology already exists to eliminate immediately the most important sources of dioxin. Other more scattered and diverse sources can easily be phased out within this decade, as long as industry is given clear instructions to do so.

Indeed, the onus is on government and industry to eliminate pollution at its source. The general public is no longer prepared to sit silent while industry and government give lectures on risk management and pollution control.

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PLANIFICATION DE L'IMPLANTATION DU PROGRAMME DE REDUCTION DES REJETS INDUSTRIELS

Ministère de l'Environnement du Québec

Ste-Foy, Québec

M. Guy Demers

TEXTE PUBLIÉ À LA PAGE 243

PAPER PUBLISHED ON PAGE 243

MANAGEMENT OF AIR BORN TOXICS IN THE U.S.A

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The subject of my talk this afternoon is "Management of Air Born Toxics in the U.S.A." Air toxics regulation in the U.S. can occur on the federal, state or local level. Also, certain other U.S. regulations, such as our volatile organic compound (VOC) or smog control regulations, or particulates controls, do a great deal to control air toxics in the U.S. Because of this, air toxics have been substantially reduced in certain areas of the country. However, there is certainly room for improvement and areas where control needs to be ensured.

Perhaps the best way to start describing the management of air toxics in the U.S. is to start with our federal Clean Air Act. The Clean Air Act has been around in some form since the 1950s. In 1970, changes were made to give the act some direction (goals) and some "teeth". The Environmental Protection Agency (EPA) was formed to do the latter. The act hasn't undergone any real change since the Clean Air Act Amendments of 1977. However, there are many bills in our Congress right now for reauthorizing/changing it. Changes are needed to continue progress in improving air quality and in meeting the original goals established in 1970.

The major provisions of the existing Federal Clean Air Act impacting air toxics are the:

- National Ambient Air Quality Standards (NAAQS),
- Non-attainment Area regulations (NA),
- Prevention of Significant Deterioration (PSD) program,
- New Source Performance Standards (NSPS), and
- National Emission Standards for Hazardous Air Pollutants (NESHAPs).

The NAAQS program sets National Ambient Air Quality Standards for certain criteria pollutants:

- lead,
- NOx,
- SOx,
- CO,
- particulates, and
- tropospheric ozone.

Our U.S. Environmental Protection Agency makes a formal determination, based on physical monitoring, as to which of about 240 air quality control regions across the country are or are not in compliance with these various NAAQS. Areas that are in compliance are subject to the Prevention of Significant Deterioration (PSD) program. Major new sources or modifications of existing sources in

PSD areas must get permits and undergo review to determine if that operation would result in a significant net increase of the criteria pollutant(s). To prevent that, Best Available Control Technology (BACT) is to be applied.

In non-attainment regions or areas that are not in compliance with a criteria pollutant NAAQS, major sources that existed when the regulations went into effect were subject to Reasonably Available Control Technology (RACT) controls. Major modifications of these sources or new sources wishing to locate in these areas are subject to Lowest Achievable Emission Rate (LAER), which is essentially the most stringent control. These sources also have to demonstrate that their new or increased emissions have been offset by reductions from elsewhere in their existing operation or from other existing sources in the area.

To better demonstrate how this leads to the management of air toxics, let's look at the criteria pollutant ozone--and I mean the lower, bad, or tropospheric ozone as opposed to the high up, good, or stratospheric ozone. Actually, ozone is the only criteria pollutant that is controlled indirectly. Therefore, the regulations control volatile organic compounds (VOCs) deemed to be one of the precursors of ozone. Our EPA originally defined a VOC as any carbon compound, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides of carbonates, ammonium carbonate or 15 other exemptable compounds, having a vapor pressure greater than 0.1 mm of mercury at one atmosphere. Now they've retracted the vapor pressure part of the definition and a VOC is essentially any volatile compound that is not photochemically reactive (those mentioned above).

Volatile organic compounds from a long series of stationary sources are regulated based on Control Technique Guideline (CTG) documents developed by the EPA to assist state and local jurisdictions in the development of air pollution control regulations. Last time I counted, I believe there were 23 CTGs. The actual VOC control regulations are implemented by the state or district. However, they are subject to very stringent EPA approval.

Besides these VOC regulations, there are more than 30 New Source Performance Standards, or NSPSs, established under Section 111 of the Clean Air Act. This set of national emission standards control both criteria and other pollutants from a wide number of new and modified stationary industrial processes. These standards were developed to prevent competition between states for new business. One state cannot apply less stringent regulations to get a new company to build there. Instead, all major sources of that type have to apply at least best available control technology. (States can, however, have more stringent controls.)

To summarize, we have National Ambient Air Quality Standards set for 6 criteria pollutants (classes). Federal EPA approved, but state or district promulgated, regulations are in place to try to achieve these standards. There are also New Source Performance Standards controlling criteria and non-criteria pollutants from a whole series of industrial processes. The resultant controls have enabled the following reductions in criteria pollutants to occur from 1978 to 1987:

	% Reductions 1978-87
lead	88%
sulfur dioxide	35%
ozone	16%

% Reduc[illegible]
1978-[illegible]
(continued)

carbon monoxide	32%
nitrogen dioxide	12%
particulates	21%

In doing so, air toxics have also been reduced since many air toxics are also VOCs or particulates. The regulations we have just talked about may not be called air toxics regulations, but they clearly have served to reduce air toxics emissions.

Now let's look at Section 112 of the Clean Air Act, which specifically deals with hazardous air pollutants or air toxics. The Clean Air Act defines a hazardous air pollutant as a compound entering the air from continuous or short term releases and causing serious irreversible or incapacitating reversible illness. Since 1970 the EPA has examined, to some extent, nearly 100 compounds or compound classes in a very detailed toxic air pollutant evaluation and control program. However, EPA has only formally listed a small number of materials as hazardous air pollutants:

asbestos,
benzene,
beryllium,
coke oven emissions,
inorganic arsenic,
mercury,
radionuclides, and
vinyl chlorides.

and subsequently developed NESHAPs (National Emission Standards for Hazardous Air Pollutants) for a limited number of source types. The compounds listed as hazardous air pollutants under Section 112 of the Clean Air Act have basically been the known human carcinogens. The EPA has run into difficulties in trying to expand this program beyond those human carcinogens, whether to probable or possible carcinogens, acute toxics or whatever. In 1985 EPA did propose listing 10 additional compounds as Section 112 hazardous air pollutants:

cadmium,
chromium,
ethylene dichloride,
1,3-butadiene,
ethylene oxide,
chloroform,
methylene chloride,
carbon tetrachloride,
trichloroethylene, and
perchloroethylene.

However, the final listing and development of NESHAPs are still on hold. A court decision on the vinyl chloride NESHAP essentially required the EPA to go back over what it had already done. In doing so, the court called on the EPA to set standards using a 2-step approach. In the first step, the identification of an acceptable risk, the EPA was prevented from considering technological feasibility and costs. The "safe" level of emissions was to be based on health aspects only. However, technological feasibility and cost could be considered in the second step, the consideration of the needed margin of safety and ultimate arrival at an actual emissions standard. Using this method EPA has proposed and promulgated new

benzene and radionuclides standards and should be ready to get on with other NESHAPs. However, proposals in the U.S. Congress are poised to totally revamp this section of the Clean Air Act--but more about that at the end.

As a result of the federal EPA's inaction, states and local air quality control agencies have developed or are in the process of developing their own air toxics programs quite apart from the federal program. All 50 states and 27 local agencies have or are doing something. Each of these programs is different, creating a situation previously called the 50-headed hydra--only now, by latest count, it's about a 77-headed hydra!

All 50 states and 16 local agencies have programs to control new sources of air toxics. Another 11 local agencies have similar programs under development. Sixteen states also control existing sources of air toxics and three more plan to. Seven local agencies formally control existing source emissions and 18 more do so on an informal, case-by-case basis or have plans for future control. Overall, the states and locals use a mix of regulatory programs, comprehensive policies, and informal case-by-case review to achieve control.

There are three typical approaches (sometimes combined) to control air toxics. The first approach is to apply safety factors to an occupational exposure limit, such as an ACGIH TLV, to get an acceptable ambient level either at the fenceline or at the nearest receptor. As to the range of safety factors used, a few years ago they ranged from 10 to 73,500. Now the range is from 4 to 7500. The two most common factors used are an adjustment from a 40 hour work week to seven days a week and 24 hours a day exposure and an adjustment for population sectors typically at greater risk (i.e., children or the elderly).

The averaging time selected also greatly affects the stringency of the acceptable ambient limit approach. Generally, the shorter the averaging time, the more stringent the limit. Averaging periods in state programs range from three minutes to annual averaging periods. Those in local programs range from 15 minutes to annual.

Districts having fewer resources (i.e., funding, toxicologists) often go the route we just discussed. For districts having sufficient resources, the risk assessment route is often used. Reviews are done of all the health, exposure, and associated data that are available on a compound before setting an acceptable exposure limit. The acceptable exposure limit may be set at a one in ten thousand, one hundred thousand or one million risk level. The risk is typically based on a theoretical person who lives on your fenceline for 70 years and is expressed as the increase probability of that person contracting cancer. The risk assessment approach is more often used with carcinogenic materials while the "fraction of the TLV" approach is typically applied to materials that are not human carcinogens.

Still another approach to management of air toxics is to automatically require technological controls such as Best Available Control Technology on compound emissions.

Depending on the number of compounds it controls, a district may combine approaches, using, for example, risk assessment on carcinogens and using a fraction of the TLV for materials that aren't known human carcinogens. They might require Best Available Control Technology and examination of any residual risk for the former and Reasonably Available Control Technology on the latter.

A check in September, 1988 showed that districts controlled from

as few as six to virtually every single air toxic in their programs. Also the check showed different districts interpreted the same health data and/or applied safety factors differently such that the same compound may or may not be controlled or may be subject to quite different control in different (even adjacent) states.

That's the status of air toxics management in the U.S.A. at this point in time. The inconsistency between neighboring states' programs and the federal and state programs is a problem in the U.S.A. There is a wide variation in the numbers of chemicals controlled as well as the levels to which they are controlled in adjacent states with identical industry. That inequitable control can have serious economic consequences for the facilities involved.

Also, there are various proposals in the U.S. Congress that would strengthen the Clean Air Act in all the areas we have just discussed. It is difficult to say if one/which one of those bills will pass. It seems likely that passage of a bill will expand VOC control by the application of regulations to larger geographical areas (i.e., not only the non-attainment area but also a ring around it) and to smaller sources. Regulations are also likely to apply to what we call area sources, i.e., dry cleaners, gas stations, bakeries, and wineries. New categories of regulation are also possible, i.e., on consumer products, architectural coatings, etc. As I explained earlier, these VOC controls will also result in control of air toxics.

There are also proposals to alter Section 112 of the Clear Air Act, the section specific to the control of hazardous air pollutants. It is certain that nearly 200 volatile compounds from a particular U.S. reporting list will be listed. Rather than a national emission standard on a given compound, the new NESHAP would control any of these nearly 200 compounds from a given usage category or operation. We expect the level of control required to be something like best available control technology (BACT) or maximum achievable control technology (MACT). The acronym varies with the particular bill. After the technology-based controls have been in place for a number of years (4-7), a review of the remaining residual risk would likely be conducted. How one defines whether the remaining risk is acceptable has been the issue most debated. Overall it is estimated that 90-99% reduction of compound emissions would be required over the next 10 years.

In the U.S. many companies have emission reduction programs already in place. My own company, The Dow Chemical Company, has been working for many years to limit emissions of pollutants through programs such as Dow's ChemAware+ enhanced product stewardship and the Chemical Manufacturers Association's Responsible Care program. As a result of our programs, Dow USA has reduced its chemical emissions by 70% from 1974 to 1984. Since 1984, we have reduced our air emissions another 50%, and we are committed to further significant reductions. We hope a new Clean Air Act will recognize the reductions we and other companies have already achieved. To require a company that has already achieved significant reductions to reduce still another 90-99% versus the same reduction requirements for a company with essentially uncontrolled emissions would be inequitable. Furthermore, it would greatly increase the cost of compliance without commensurate environmental benefit.

+Service Mark of The Dow Chemical Company

A new Clean Air Act is needed in the U.S. Dow supports legislation that would enable the EPA to address emissions of toxic air pollutants in an effective and timely manner. We believe the EPA can do this by requiring that emitters of toxics install the appropriate pollution control technology to minimize these pollutants and substantially reduce any risk associated with them. Setting technology-based standards is a vital first step. The second step is to determine whether any unreasonable risk remains after controls have been put into place. We believe arbitrary numerical risk standards should not be used to define that unreasonable risk, because the complexity of the science of risk assessment does not lend itself to being stated as a single risk number--like one in a million--for all pollutants. Instead, we believe appropriate guidelines should be set for the EPA to follow in setting risk standards on a case-by-case basis. We believe this would lead to appropriate and consistent management of air born toxics in the U.S.A. Consideration of the same approach in Canada would benefit our entire continent.

2/7/90

CONTROL PROGRAMS OF THE ECONOMIC EUROPEAN COMMUNITY

Commission of the European Communities

Italy

Environment Institute

Mr. Walter Karcher

Paper unavailable at time of printing

Texte non reçu au moment de mettre sous presse

UN APERÇU DES ORIENTATIONS DE LA COMMISSION D'ENQUÊTE SUR LES DÉCHETS DANGEREUX DU B.A.P.E.

Commission d'enquête sur les déchets dangereux

Montréal, Québec

M. Yvon Charbonneau, Président

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THE CANADIAN ENVIRONMENTAL PROTECTION ACT

Environment Canada

Mr. Glenn Allard

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DOES CEPA RECOGNIZE SUSTAINABLE DEVELOPMENT

Canadian Chemical Producers Association

Mr. W. Neff

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CANADIAN APPROACH TO CHEMICAL SAFETY

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Presented at the FOURTH CONFERENCE ON TOXIC SUBSTANCES
Montreal, Quebec, April 4 and 5, 1990

The extensive and ever increasing use of chemical substances in industry, in agriculture and in consumer products has brought many benefits to society. In Canada and many other countries, we have become a 'chemical society'. However, the use of certain chemicals in commerce has, on occasion, resulted in injury to man or the environment. In recent years, society has become aware of the potential for harm which certain chemicals may pose because of the improper use, handling or disposal of many of these substances. Sensational reports frequently appear in the news media about the alleged risks caused by chemicals, which have induced public anxiety. One of the main factors contributing to this anxiety is the inadequate knowledge of the possible adverse effects which a chemical can have on human health or the environment. As a result, in Canada and in many other countries, the tide of public opinion favours a continual reduction in environmental hazards.

Canada is a partner in the international market in chemicals. For example, in 1984 Canada produced $15.5 billion worth of chemicals, imported $5.4 billion worth and exported $4.1 billion worth (*Figure 1*). There have been many estimates made of the number of chemicals in use around the world, ranging from 60,000 to over 100,000. It has been estimated that about 30,000 chemicals are used commercially in Canada, most of them being synthetic. Clearly it would be a difficult, if not impossible, task to determine the toxicity of each of the chemicals in Canadian commerce, let alone those in commerce around the world.

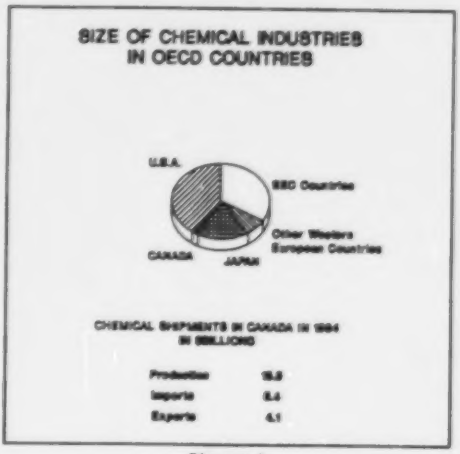

Figure 1

Obviously, the task of governments in dealing with the issues presented by chemicals in the environment is not an easy one. Most of these chemicals have benefits associated with their use. In an ideal world, the evaluation and control of risks from chemicals would be conducted systematically, so that each identified risk would be dealt with in a consistent and expeditious manner. However, I am not aware of any government which has developed a consistent and adequate policy for the management of all aspects of risks due to chemicals.

FEDERAL-PROVINCIAL DIVISION OF POWERS

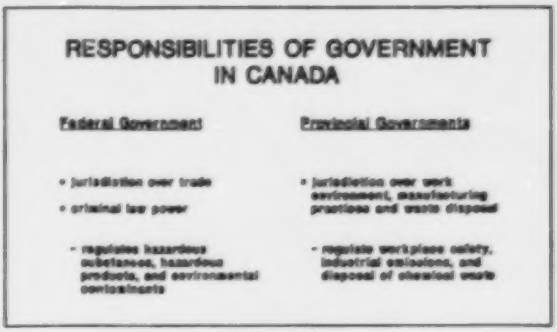

Figure 2

Canada has a federal system of government. The Constitution Acts of 1867 and 1982 specify the areas of federal and provincial jurisdiction (*Figure 2*). The **federal government**, through its criminal law powers and its jurisdiction over interprovincial and international trade and commerce, has the authority to regulate hazardous substances, hazardous products and environmental contaminants. The **provinces** have authority within their boundaries over manufacturing, the work environment, waste disposal, and the provision of health care services, as well as control over environmental management (through their ownership of natural resources). The **federal government** also has emergency powers and any residual powers not specifically assigned to provincial governments. In principle, control of toxic substances is required from manufacture to disposal, or, more colloquially, from "cradle to grave". Legislative control, both federal and provincial, can cover the following elements: manufacture, importation, occupational health, transportation, storage and handling, use or sale, discharge to the environment, waste disposal and spills. There are some 27 federal statutes which provide some form of control over toxic substances; in addition, the ten provinces have enacted about 100 pieces of legislation.

LEGISLATIVE FRAMEWORK IN CANADA

The first Canadian legislation which allowed for some control of toxic substances, was passed in 1875, and was intended to combat the fraudulent practice, common at the time, of adulteration of food and medicines with foreign matter. From these early beginnings, Canadian legislation to control chemicals evolved towards resource protection, to consumer protection, to worker protection, and to protection of the environment and the public. The relevant federal legislation may be classified as follows:

i. General Pollution Statutes (intended to control contamination of water, air or soil)

The **Canada Water Act** (1969) enables the government, in conjunction with the provinces, to manage the quality of water bodies, and provides for monitoring and research.

The **Clean Air Act** (1971) was used to set specific air emission standards and national air ambient air quality objectives. In June 1988 it was subsumed into the Canadian Environmental Protection Act (see below).

The **Fisheries Act** (1939) was the first Canadian environmentally oriented law, although its intent was not so much to protect the environment for its own sake, but rather to protect fish habitats. It is principally used to protect commercial fisheries, but also has the value of protecting the environment.

ii. General Contaminants Control Statutes (directed at controlling specific chemicals)

The **Canadian Environmental Protection Act** is a powerful piece of new legislation which was promulgated on June 30, 1988, and replaces the Environmental Contaminants Act. It provides the power to regulate toxic chemicals which cannot be controlled by other legislation. In particular, it provides for notification to the government of new chemicals before manufacture or importation.

iii. Food and Drug Statutes (intended to preserve and improve the quality of food and drugs)

The **Food and Drugs Act** was promulgated in 1920, and had broad powers to control food and drug quality. The Food and Drugs Act was last revised in 1953, and is now a mature piece of legislation. Over the years more than 175 pages of regulations have been developed. It provides for control of toxic chemicals in foods, drugs, cosmetics, and medical devices. For example, maximum residue levels for a wide variety of chemicals in food have been established. It is important to note, however, that the Food and Drugs Act focuses upon control of the product containing the toxic substance, rather than upon control of the contaminant itself.

iv. Consumer Safety Statutes (directed at particular products used by the public)

The **Hazardous Products Act** was enacted in 1968, and is directed at protecting the consumer from hazardous products, including hazards from toxic chemicals. It was a pioneering piece of legislation since, at the time, no other country had any comparable law.

The **Pest Control Products Act**, also promulgated in 1968, is designed to control products used for the control of pests. Pesticides must be registered under this Act before they can be used in Canada, and detailed regulations have been promulgated prescribing information requirements for registration.

v. Transportation Statutes (to protect public health and safety and the environment during the transport of dangerous goods)

The **Transport of Dangerous Goods Act** (1980) mandates the application of certain safety standards for handling and transportation of goods as well as standards for containers and packaging.

vi. Workplace Contaminants Control (to protect workers' health and safety in specific industries)

The **Canada Labour Code**, enacted in 1967, affects workplace safety conditions for employees involved in federal works, businesses and undertakings. It provides authority to make regulations respecting the handling, transportation, storage, use and disposal of toxic substances. Similar legislation exists within provincial jurisdictions.

The **Hazardous Products Act Part II** requires that suppliers of materials manufactured or sold for use within the workplace provide information to employers and, in turn, to employees. The information to be supplied includes the name of each ingredient and its concentration, together with information on the hazards associated with the product. This is done by means of appropriate labelling and the provision of a material safety data sheet (MSDS).

The **Hazardous Materials Information Review Act** provides for exemption from disclosure of certain information on the label or MSDS of a product based upon the need to protect confidential business information, such as trade secrets. The type of information which can be withheld is the chemical name of certain ingredients and their concentration. However, information on health hazards cannot be claimed as confidential and must be disclosed.

vii. Statutes Regulating Specific Industries

There are several groups of federal statutes, such as the Canada Shipping Act and the Fisheries Act, which can be used to establish specific standards for emissions from particular industries.

Traditionally, therefore, legislation in Canada has provided a dual approach to control of chemicals (Figure 3):

(i) the licensing before they are marketed of specific groups of chemicals, such as drugs, food additives and pesticides, which have the potential to be harmful, especially to human health, and

(ii) the control of existing chemical substances which have come to be regarded as toxic pollutants.

The first of these is preventive in that it attempts to identify and evaluate chemicals that might be harmful before man is exposed to them. The onus is on the manufacturer or importer to apply for permission to sell a chemical for use in one of these regulated categories. The petitioner must submit evidence in support of his application which demonstrates to the satisfaction of the government that the chemical is efficacious and safe for the intended use. If successful, the chemical is then registered for a specific use, and often certain limitations are placed on the use of the chemical. In Canada, registration of chemicals is required by law for drugs and food additives, because they are intended for direct human consumption, and for pesticides, because by their nature they are toxic.

APPROACHES TO CONTROL OF CHEMICALS

LICENCING BEFORE MARKETING	CONTROL OF EXISTING CHEMICALS
• preventive - manufacturer must demonstrate safety	• controls chemicals already in use after they are found to be toxic
• used where direct human exposure anticipated	• used where direct human exposure is not expected
• expensive	• less costly to industry
• traditionally used for food additives, drugs and pesticides	• generally used for all other classes of industrial chemicals

Figure 3

The second area is usually an attempt to control a chemical after it has become evident that some harm or damage has occurred, or is likely to occur. It can take the form of controls on release or emissions of the chemical, or the establishment of quality standards, usually maximum concentrations in various media or commodities, e.g. food items. In this case the onus is on the government to identify the existence of a risk to health or the environment, and to implement appropriate corrective action.

REGISTRATION OF NEW CHEMICALS

In Canada, the primary legislation for the control of pesticides is the Pest Control Products Act (P.C.P. Act), which is administered by the Department of Agriculture. The Act attempts to ensure that pesticides are not used which are unsafe to human health or the environment. It also tries to ensure that only pesticides are approved which are effective for their intended purposes. The review process is shown in Figure 4. The manufacturer must apply to the Department of Agriculture and provide a supporting data package.

The process for registering pesticides provides an example of the preventive approach for controlling chemicals. The Department of Agriculture coordinates the review of the data package by other federal Departments - Health and Welfare, Environment, Fisheries and

Oceans, and Agriculture itself. For example, Health and Welfare reviews the information as it relates to risks to health of people involved in manufacture, handling or application of a pesticide, as well the potential risks to bystanders. Health and Welfare is also responsible for ensuring that the use of a pesticide on food crops will not result in residues on food that may be hazardous to health. The data package provided by the manufacturer can take up to 10 years to develop at a cost of up to $20 million. The data for assessing the potential health effects is generated using laboratory animals. Four kinds of studies are performed: 1) acute studies (single exposure); 2) short term studies (multiple exposure - 10% of lifespan); 3) long term studies (multiple exposure - two-thirds of lifespan); and 4) special studies such as teratology and mutagenicity studies. The manufacturer must also provide some indication of the likely exposure of applicators and bystanders to the pesticide during normal use -usually via the inhalation or dermal route. The Department of National Health and Welfare and the other Departments involved make their recommendations to the Department of Agriculture based on their review of the data package, and the Department of Agriculture makes the regulatory decision. Provision is also made in the P.C.P. Act for re-evaluation of established pesticides in light of new information. In this way, a registered pesticide can be withdrawn from the market, i.e. de-registered, if new data show that the risks outweigh the benefits. A recent example is that of Alachlor which was de-registered in 1985, because of studies which showed it to be a potent carcinogen.

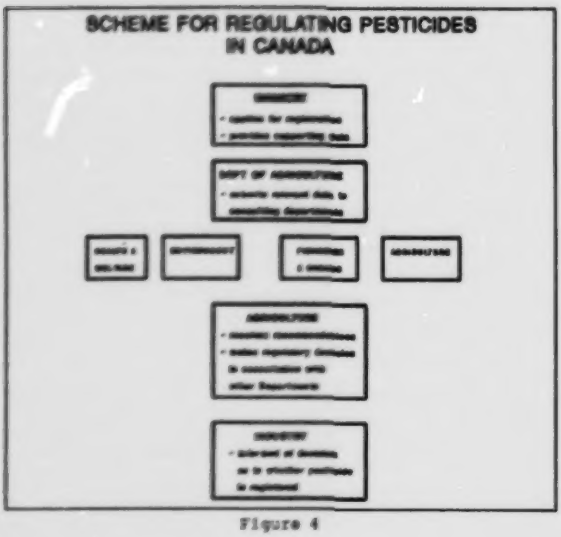

Figure 4

The preventive approach to the control of chemicals is also now being taken in Canada for all new chemicals, whatever their intended use. The concept of identifying and evaluating potential hazards associated with industrial chemicals before they are manufactured or imported has been incorporated into the new Canadian Environmental Protection Act (CEPA). This Act provides new powers that include the authority to regulate all phases of the life-cycle of chemicals from development, to manufacture, to storage, to transportation, to use and finally to disposal, where these aspects are not encompassed in other, more appropriate legislation. A few of the highlights of CEPA will now be discussed.

Firstly, under CEPA, new chemicals will have to be tested and evaluated before either manufacture or importation (Figure 5). The actual toxicity and other data to be provided depends upon the quantity of the substance to be manufactured or imported. Quantity triggers are used as a measure of potential exposure to man or the environment (Figure 6). As more exposure is foreseen to be likely, more test data will be required. Test requirements for chemicals made or imported between 5 and 300 kg per year are shown in the column 1 of figure 6. For chemicals in the range 300 - 1000 kg per year the data requirements are increased (column 2). For chemicals manufactured or imported in greater than 1000 kg quantities per year a full data package is needed (column 3). These data requirements are not as comprehensive as those required for registration of new drugs, food additives or pesticides. However, industrial chemicals are not intended for direct human consumption, nor, unlike pesticides, are they intended to be toxic or applied directly to the environment. These minimum data packages are therefore felt to be sufficient to provide for a first meaningful assessment of the potential risk to health and the environment. If the data provided suggest that a risk to man or the environment may occur, the Act provides the power both to restrict the conditions of use and to require that more testing be done. The scheme to be followed is similar to that used for new pesticides (Figure 5). In this case, however, only two Departments are involved - Health & Welfare and Environment.

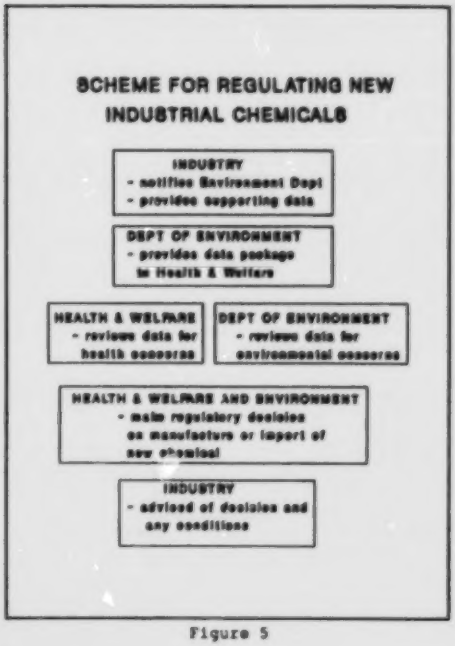

Figure 5

The regulatory provisions for new chemicals will come into force once an inventory of chemicals currently in use in Canada has been developed - to be known as the Domestic Substances List. This will take about 2 years to complete and is necessary so that the government can determine what is a new chemical. A chemical not on the Domestic Substances List will be treated as a new chemical for the purposes of the Act. Manufacture or import of **existing chemicals** will, of course, be permitted without further testing.

LEVEL 1

5 - 300 kg/year

Identity (IUPAC nomenclature)

CAS number

All available information in the possession of notifier on health and environmental effects

Intended use

LEVEL 2

300 - 1000 kg/year

Identity (IUPAC nomenclature)

CAS number

Material safety data sheet and a label

All available information in the possession of notifier on health and environmental effects

Intended use

Physico-chemical data (excluding adsorption and hydrolysis data)

One acute mammalian toxicity test representing the most probable route of exposure

Expected quantity to be used each year

Estimated number of people likely to be exposed

expected emissions and discharges to the environment

Recommended disposal method

LEVEL 3

More than 1000 kg/year

Identity (IUPAC nomenclature)

CAS number

Material safety data sheet and a label

All available information in the possession of notifier on health and environmental effects

Intended use

Physico-chemical data (excluding adsorption and hydrolysis data)

Two acute mammalian toxicity tests representing the most probable route of exposure

Expected quantity to be used each year

Estimated number of people likely to be exposed

expected emissions and discharges to the environment

Recommended disposal method

Mutagenicity data

Ecological data:
- fish LC_{50}
- daphnia LC_{50}
- biodegradation
- bioaccumulation

Repeated dose mammalian toxicity test (28 day study)

Figure 6

REGULATION OF EXISTING CHEMICALS

With respect to the control of existing chemicals, i.e. chemicals already in commerce, it was pointed out above that this is usually an attempt to control a chemical after it has become evident that some harm or damage has occurred. There are several Canadian laws which can be used to deal with specific aspects of problems caused by existing chemicals. However, in addition to dealing with new chemicals, the new Canadian Environmental Protection Act also addresses the question of existing chemicals, and does so in a systematic manner. The Act requires that a list of priority chemicals be established for assessment to determine whether further controls need to be imposed on them. The first list of priority chemicals for assessment was published on February 11, 1989.

The Priority Substances List is intended to be a dynamic list which both identifies the concerns of the citizens of Canada and which sets a realistic timetable for the government in dealing with existing chemicals. The list is compiled in consultation with provincial governments, labour groups, industry and associations or persons concerned with environmental and health matters. Furthermore, any person may petition the Minister of Environment to request that a substance be added to the Priority Substances List (with reasons for adding the substance to the list); Ministers (Health and Environment) must respond within 90 days giving reasons for their decision.

The law requires that each substance on the list be the subject of an assessment within a five year period to determine whether it is "toxic" within the meaning of the legislation[1].

CEPA requires that the Ministers prepare a report of the assessment and that the report be made available to the public. Ministers must declare whether they intend to schedule the substance (if it is determined to be toxic) or not. In the latter case, anyone may, within 60 days, file a Notice of Objection whereupon the decision is referred to a Board of Review. In the event of a substance being declared toxic, Ministers must also indicate the nature of regulations they intend to propose.

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[1] Under the Canadian Environmental Protection Act, a substance is deemed toxic if:

"it is entering or may enter the environment in a quantity or concentration or under conditions

(a) having or that may have an immediate or long-term harmful effects on the environment;

(b) constituting or that may constitute a danger to the environment on which human life depends; or

(c) constituting or that may constitute a danger in Canada to human life or health."

Table I. Canadian Priority Substances List

Group	Substance
1	Arsenic and its compounds
	Benzene
	Effluents from pulp mills using bleaching
	Hexachlorobenzene
	Methyl tertiary-butyl ether
	Polychlorinated dibenzodioxins
	Polychlorinated dibenzofurans
	Polycyclic aromatic hydrocarbons
	Waste crankcase oils
2	Cadmium and its compounds
	Chlorinated wastewater effluents
	Chlorobenzene
	Chromium and its compounds
	Creosote impregnated waste materials
	Dibutyl phthalate
	1,2-Dichlorobenzene
	1,4-Dichlorobenzene
	1,2-Dichloroethane
	Dichloromethane
	Di-n-octyl phthalate
	bis-(2-Ethylhexyl) phthalate
	Inorganic fluorides
	Nickel and its compounds
	Pentchlorobenzene
	Styrene
	Tetrachlorobenzenes
	1,1,2,2-Tetrachloroethane
	Toluene
	Trichlorobenzenes
	1,1,1-Trichloroethane
	Trichloroethylene
	Xylenes
3	Aniline
	Benzidine
	Chlorinated paraffin waxes
	bis(2-Chloroethyl) ether
	bis(Chloromethyl) ether
	Chloromethyl methyl ether
	3,3'-Dichlorobenzidine
	3,5-Dimethylaniline
	Methyl methacrylate
	Mineral Fibres
	Organotin compounds (non-pesticidal uses)

In this way, the Canadian government has, in effect, legislated a strict schedule for dealing with lists of existing chemicals that are identified as being of concern to its citizens.

The first Priority Substances List includes 44 entries (Table I). These include single substances (e.g., benzene), classes of substances (e.g., polynuclear aromatic hydrocarbons, polychlorinated dibenzofurans) and mixtures of substances that originate from a specified source, process or activity (e.g., effluents from pulp mills using bleaching, creosote-impregnated waste materials).

Risk Assessment and Risk Management

Effective control of existing chemicals flows from a systematic examination of the risk, an evaluation of socio-economic factors, and finally management of the risk. A number of models for risk assessment and risk management have been proposed in recent years, but they are all generally similar. Figure 7 shows the process used by the Environmental Health Directorate, Department of National Health and Welfare, to assess and manage risks to health from existing chemicals.

The first step in this risk assessment - risk management process is **hazard identification**, which means recognition that a particular hazard exists. A hazard may be identified in a variety of ways, including case reports, toxicological studies, and epidemiological investigations.

The next step is **risk estimation**, which involves quantitative estimation of risk or risks associated with the identified hazard. Such estimates are usually based on the analysis of epidemiological and toxicological data as well as estimation of levels of human exposure. It is often necessary to extrapolate information obtained from animal studies to man. And furthermore, it is also frequently necessary to extrapolate dose-response data from high to low doses, and mathematical models are often used for this purpose. Such extrapolations carry with them a considerable amount of uncertainty, because of limited understanding of the relevant biological processes. Dose-response data is also, of course, the type of information used to develop exposure standards - essentially the reverse of determining the level of risk. Exposure estimation involves describing the nature and size of the exposed population, as well as magnitude and duration of their exposure.

The third stage is **option evaluation**, which has two components - **development of options** and **option analysis**. **Development of options** involves formulation of a number of alternative courses of action to deal with a problem. Options may be regulatory or non-regulatory, and can range from an outright ban of a substance to economic incentives or provision of advice to the public. **Option analysis** requires consideration of potential options in light of other factors such as:

- health risk versus health benefits
- the acceptability of the risk to the public
- the technical feasibility of the proposed courses of action
- economic impact of options.

The three steps discussed above (hazard identification, risk estimation, and option evaluation) comprise the **risk assessment** portion of the model. The remaining steps comprise **risk management**.

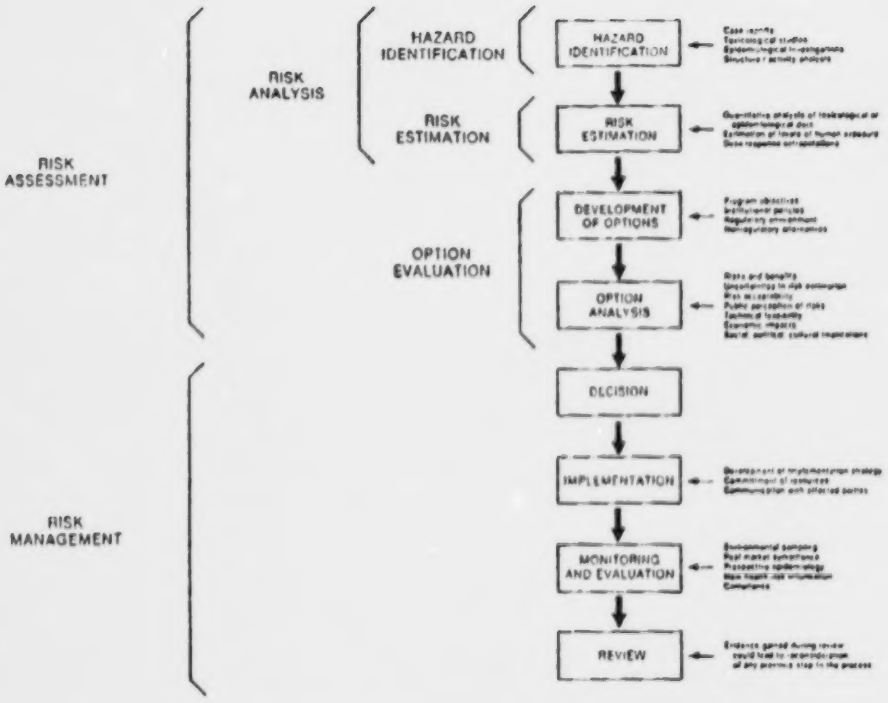

Figure 7. Risk assessment/risk management model

Risk management begins with the **decision** as to which particular strategy or option will be chosen to deal with the perceived risk. It is also possible, and indeed likely, that more than one option may be chosen for implementation simultaneously. **Implementation** of the **decision** will entail the development of a strategy and will usually require commitment of resources, and should, in most cases, be conducted in consultation with the affected parties. Once the strategy to control the perceived hazard is in place, feedback on the suitability and impact of the process can be obtained through compliance **monitoring and evaluation**. Techniques such as environmental monitoring or market surveillance can be used for this purpose. Finally, a **review** of the whole process, after a suitable period of time, may provide valuable information on each step and a new insight into the decisions taken.

STANDARDS

Regulatory agencies generally need to use standards in order to implement regulations to control risks from existing toxic chemicals, unless, of course, the risks are so great that no use of the chemical whatsoever can be permitted. Standards used by regulators are usually expressed as numbers, and in the case of chemicals, usually some sort of concentration value. No matter what sort of regulatory action is being considered, a standard provides a reference point for enforcement and surveillance. In reality, the standard enables the regulator to make a judgement between what is safe and what is harmful or criminal - or, more correctly, between what is an **acceptable risk** and what is an **unacceptable risk**. Even the best standards, however, will only be an approximation for the purposes of health protection and will not give an absolute guarantee of freedom from risk.

Types of Environmental Standards

In general there are three types of environmental standards - environmental quality standards, emission and effluent standards, and product standards (Figure 8).

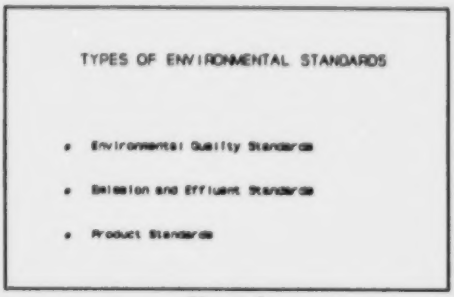

Figure 8

Environmental quality standards prescribe the maximum allowable levels (or sometimes the minimum allowable levels) of pollutants in media such as air, water or soil. They may be designed to cover certain geographical areas e.g. national, provincial or local. However, in some instances, it may not be wise only to set a maximum allowable level for a chemical pollutant in the environment. It may be used as a licence to pollute to the maximum level. It may, therefore, be useful to designate a lower level as a long term objective for environmental quality. This concept is incorporated, for example, into the National Air Quality Objectives which have three levels: 'tolerable', 'acceptable' and 'desirable'. The first sets the concentration which poses a threat to human health, the second provides adequate protection to human beings and the environment, while the third is a long term goal for sound environmental quality.

Emission and effluent standards specify the maximum amounts or concentrations of pollutants that may be released into the environment. In some instances, a particular process or mode of operation may be specified as the means to achieve an emission standard.

Product standards specify limits based on the properties of the product, its packaging or its emissions. Examples are pollutant limits in food products for heavy metals and pesticides.

Derivation of Exposure Standards

In order to establish accurate, defensible, health-based exposure standards, it is essential to determine the quantitative relationship between a given pollutant and its effects, i.e. the so-called **dose-response** relationship. Because of ethical considerations, it is usually difficult to obtain such information from studies on human populations. Rather regulatory agencies use laboratory animals and generally attempt to determine a level of exposure below which there are no apparent adverse effects using laboratory animals - the No-Observed-Adverse-Effect-Level (Figure 9). An uncertainty factor is then incorporated in order to derive a regulatory standard or guideline. The size of uncertainty factor depends upon the type and quality of the available data, and is generally in the range of 100 to 5000. The use of this approach implies that there is a threshold dose below which an adverse effect is presumed not to occur.

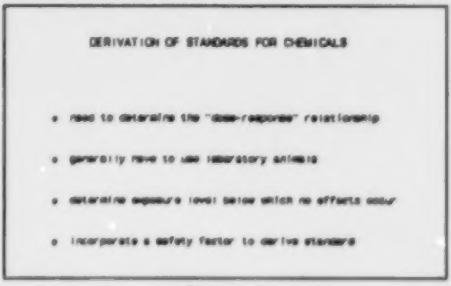

Figure 9

For carcinogenic substances, it is assumed that there is some probability of harm at any level of exposure. Consequently, there is no threshold of exposure below which adverse effects will not occur, and therefore it is not appropriate to derive standards using the approach just described. Nevertheless, the incremental risk which a carcinogen poses to health decreases as the degree of exposure decreases. At sufficiently low exposures the risk posed by a carcinogenic chemical may be so small as to be **essentially negligible or de minimis,** especially in comparison to other risks commonly encountered in society. In recent years, a variety of quantitative risk estimation methods have developed for dealing with carcinogenic effects. It is possible to calculate the degree of risk which is associated with a given level of exposure to a chemical. However, there are many uncertainties in the quantitative risk assessment process. In Canada, therefore,

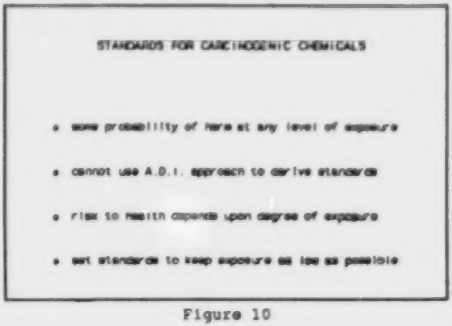

Figure 10

we do not use risk estimation techniques to derive standards for carcinogenic substances. Rather, we try to keep exposure to carcinogens as low as possible, and use quantitative risk estimation to put a standard derived in this way into perspective.

Multimedia Approach to Standard Setting

The widespread use of chemicals has led to their dispersion throughout the environment, such that they can be found in air, food, water and soil. Legislation, however, has usually been developed to deal with chemical contaminants on a medium-by-medium basis. Recently, we have been paying attention to controlling risks to health on a **multi-media** basis. This approach is designed primarily to ensure that human exposure to a toxic chemical from all possible pathways does not exceed an **acceptable** or **allowable** value. It implies that when a chemical is under assessment, all routes of exposure should be evaluated and controls or regulations should be developed taking into account the principal exposure pathways.

EXPORT RESTRICTIONS

Finally, the new Canadian legislation has also recognized that toxic chemicals are a global problem. There are new restrictions on the export of chemicals from Canada to other countries (Figure 11). A chemical which is banned in Canada cannot now be exported to another country, except for the purpose of disposal and with the permission of the importing country. A chemical which is severely restricted in Canada can only be exported after the Canadian government and the government of the importing country have been informed. It is hoped that this will enhance international cooperation among countries for safe handling and disposal of toxic chemicals.

CANADIAN ENVIRONMENTAL PROTECTION ACT
Section 41 (2) "Export of Toxic Substances"

No person shall export any toxic substance specified on the List of Prohibited Substances in Part I of Schedule II except for the purpose of destroying the substance or complying with a direction under subparagraph 40 (2) (iii)

Figure 11

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INTERNATIONAL APPROACHES TO ESTABLISHING SITE CLEANUP LEVELS: AN EVALUATION OF DIFFERENT METHODS

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Keywords

Cleanup criteria, remediation, soil, methodology, risk assessment, international, HESP, AERIS.

Hazardous waste sites throughout the world are cleaned up to levels which are intended to protect health and the environment from adverse effects due to exposure to contaminants. However, a comparison among different methods used to derive site cleanup levels shows there is little scientific basis for how many of these levels are derived and therefore little basis for knowing whether these levels are also truly protective of health and the environment. Deriving non-scientific cleanup levels is also an economic concern, as these site cleanup levels are often the main determinant of site cleanup costs, which nowadays can easily run into millions of dollars.

Therefore, increasing emphasis should be placed on developing *scientifically defensible* criteria which will ensure sites are cleaned up to levels which are truly protective -- i.e., cleaned up to levels which will provide adequate protection of health and the environment, but not cleaned up more than is necessary, which will take away funds needed to clean up other sites and address other health threats.

This paper discusses the ideal components of a system to determine cleanup levels, and assesses various methods used throughout the world to derive cleanup levels in light of these criteria. Systems based on "absolute" (generic) and "relative" (site-specific) approaches, as well as systems which combine the two approaches, are discussed in detail. The "relative" approach was found to be the most reliable means of protecting health and the environment, and is also the most cost-effective, whereas cleanup levels based on an "absolute" approach were not found to be scientifically, economically, or politically defensible.

It is recommended that the *process* by which cleanup levels are determined should be standardized, not the levels themselves, which of necessity vary from site to site. Several criteria are presented as the basis of a sound scientific method for determining soil cleanup levels. Two models (HESP and AERIS) are evaluated for their ability to meet these criteria.

I. INTRODUCTION

Recent reviews of site cleanup levels throughout the world show that two to three orders of magnitude difference between cleanup levels is not uncommon (see Table I). The question then becomes, do levels vary because site conditions vary substantially between the sites, or because the scientific basis for some cleanup levels is stronger than for others?

The answer appears to be, both are true. The sources, receptors, pathways, and contaminants of concern all vary considerably from site to site, and many of the cleanup levels take those considerations into account. As such, one would expect the cleanup numbers to vary between sites, often significantly. This is described as the "relative" approach to setting site cleanup levels.

TABLE I

VARIATION IN SOIL CLEANUP LEVELS FOR LEAD

Country	ppm in Soil
US Envir. Protection Agency	20-166.5
New Jersey, USA	100
California, USA	1,000
Alberta, Canada	800 (pH<6.5)
British Columbia, Canada	500
Quebec, Canada	200
United Kingdom (residential)	500
(park)	2,000
France	100-500
The Netherlands	150

Notes:

Criteria from the USA are largely based on EPA Records of Decision at Superfund sites (USEPA, 1988). Criteria reported for The Netherlands and Canada are category "B" (requires detailed analysis and some restorative or reclamation for residential, agricultural, or recreational use). The rationale behind the establishment of these standards was not available in many cases. In addition, there are factors other than protection of health and the environment that often influence cleanup levels, including background concentrations, economic considerations, technical feasibility, and social or political concerns. As a result, the criteria may or may not be scientifically defensible and comparisons between values may be scientifically irrelevant.

However, some cleanup levels are also based on a less than soundly scientific approach, whereby generic "trigger" or "threshold" levels are established for a given contaminant. This level is intended to apply to a variety of sites, below which a site is considered "safe" and above which remediation is recommended. This is called an "absolute" approach, because the same number is applied no matter what the site conditions and regardless of the actual hazard or risk present. These numbers tend to vary considerably between countries according to the criteria used to establish those levels (often including considerations of cost, sociopolitical concerns, available technology, regulatory constraints, etc.).

Many countries adopted these "absolute" values because they are simple to develop and were thought to be easy to implement and enforce. This means the absolute numbers have to be conservative enough to provide adequate protection at the majority of sites. Unfortunately, several deficiencies have been found with this approach, such that the levels are in fact difficult to implement; hence, many countries may be reconsidering the absolute approach.

This paper establishes criteria for an ideal method for establishing soil cleanup levels, describes the various methods currently employed to establish cleanup levels, and assesses two models currently under development for their ability to meet these criteria.

II. FEATURES OF AN IDEAL METHOD TO DETERMINE SOIL CLEANUP LEVELS

The first step in constructing a method for establishing soil cleanup levels is to decide on the criteria which that method should reflect. In a recent comprehensive survey (Environment Canada, 1988), the Canadian Council of Resource and Environmental Ministers (CCREM) recognized the inconsistency of the various approaches used in Canada to develop soil cleanup levels, and recommended that a uniform approach be established for the development of cleanup levels. This approach should incorporate site-specific characteristics and be protective of both human health and the environment. The criteria they used for establishing this method were as follows, with several additions to the list:

Be Consistent: The process for deriving site cleanup levels needs to be uniform to allow "fair" decision making. This requires the use of consistency among the assumptions and guidelines for determining hazard and risk. In the absence of uniform guidelines, the process will be perceived to be unfair (and may well be).

Be Flexible: The method should be flexible enough that "site specificity can be maintained despite the wide diversity of sites and situations for which cleanup criteria will be required" (Environment Canada 1988).

Incorporate Site-Specific Data: It should be capable of allowing for site-specific variations in the chemical, biological, and physical environment. "Site-specific factors, variable background levels, fluctuating and sometimes widely varying environmental conditions (e.g., climate), bioavailability and chemical speciation should always be considered" (Poels, 1989).

Address All Environmental Media: Current methods for developing site cleanup levels focus on one major route of exposure to the exclusion of others. In several instances, some of the secondary pathways of exposure have become significant sources as well. All relevant pathways of exposure should be screened for their potential to become a significant source of exposure, including any medium constituting a sink, temporary storage, or conveyance for contaminants. Otherwise, risk could be substantially underestimated.

Address All Environmental Contaminants of Concern: The method should incorporate any and all environmental contaminants of concern, either singly or in combination. However, as not all chemicals present necessarily pose a health risk, the method should incorporate a screening process to allow prioritization of those chemicals on site which are truly of concern which then require further evaluation. The substances should be screened according to inherent toxicity, quantity present, and particular properties such as persistence in the environment or potential to bioaccumulate.

Distinguish Various Degrees or Periods of Contaminant Exposure: It should distinguish between various degrees or lengths of contaminant exposure to a biological receptor.

Deal with Various Routes of Exposure: The process should address ingestion, inhalation, and dermal exposure to contamination. To exclude one of these routes of exposure would not allow a full determination of hazard. Furthermore, evaluate various routes and pathways both singly and in combination, as well as assess effects on the biological receptor.

Deal with Various Receptors: Non-human receptors are often of greater interest than human exposure to contamination. The method should be able to assess not only differences in the human population (e.g., evaluate sensitive populations such as children and the elderly), but also assess terrestrial and aquatic species of interest as well as vegetation.

Deal with the Effect of More Than One Contaminant Exposure to a Biological Receptor: It should simultaneously incorporate the effect of more than one contaminant on a biological receptor.

Differentiate Between Non-Carcinogenic and Carcinogenic Contaminants: It should address biological endpoints of concern other than cancer (e.g., reproductive effects).

Incorporate Risk Assessment: It should be able to incorporate risk assessment into the development of quantitative cleanup criteria, i.e., the probability that a given effect will occur due to the existence of a hazard.

Deal with Missing Data: Hazard and risk assessments involve a great deal of unquantified and unknown data. The method should contain some means of assessing variables for which little data exist, including use of appropriate uncertainty factors, as well as be able to incorporate future data as it develops.

Incorporate Desired End Land Use: The method should recognize differences between sites, e.g., reflect the difference between an industrial site and a daycare center in calculating estimates of potential exposure and not require that all sites be treated alike as though these differences did not exist.

Provide Adequate Documentation of All Calculations and Values: Hazard and risk assessment is no place for black boxes. All calculations and input values used to calculate hazard and risk should be well documented and readily available for public review and discussion. This is an extremely important criterion.

Provide Quantitative Evaluation: Qualitative estimates are less useful in effecting site cleanups than quantitative estimates, even with the uncertainty associated with those estimates. It is difficult to know how to clean up a site ranked "highly" or "moderately" contaminated.

Be "User-Friendly:" It can be seen from the above that to be adequately comprehensive, dozens of calculations may be required to properly determine cleanup levels. These calculations are best carried out as a computer model in order to ensure ease of use and minimize errors, but be structured so that it is easy to use by trained professionals.

Be Cost-Effective: There is no magic to these calculations. The value of the model is the scientific thinking that goes into selection of the input parameters, not the equations themselves. The model should be readily available to the public in a form that is easy to use and at minimal cost, since the calculations are fairly well established and the development costs of compiling these calculations into a model should not be high. In this way, the model is more likely to be used for related purposes as well, such as in making decisions about site contaminants in the area of property transfers, etc.

III. EXISTING METHODS FOR DEVELOPMENT OF CLEANUP CRITERIA

On the basis of the above criteria, the CCREM recommended that a combined approach be investigated which would incorporate elements from both the absolute and relative strategies. It was believed that this approach would allow the development of a scientifically defensible, easily standardized, and "user-friendly" system which would also provide the most cost-effective means of developing cleanup levels for a wide diversity of sites.

This section describes the existing absolute and relative approaches, and concludes with an evaluation of two new models that have recently been developed which combine selected aspects of the absolute and relative approaches.

A. Absolute Approach

This approach entails establishing a fixed concentration for a given contaminant in a specific medium which is applicable to all sites and below which no adverse health effects are expected. An analogy would be establishing a speed on the road below which no vehicle is allowed to travel, no matter what type of vehicle (car? truck?) or driver (adult? child?) or street condition (highway? dirt road?) or weather (sunshine? snow?).

Such a standard appears to be simple to establish, easy to implement and enforce, but in fact is totally impractical as it does not take into account the reality and uniqueness of each driving situation (or site condition). In addition, it is also not a fair or cost-effective approach, as a speed would have to be established which is protective of the vast majority of drivers and vehicles, which means most vehicles would be driving at a slow speed which may not be not fuel-efficient. Furthermore, such a standard does not take into account the fact that some of the vehicles would be designed to travel at a higher rate of speed than others without a corresponding increase in risk (a convertible vs. a truck).

Advantages

The advantages of the absolute approach is that it is easy to implement and simple to use, at least initially. "It appears to be an objective process, grounded in scientific analysis and free of value judgments, and relieves policy makers from a cumbersome burden of dealing with uncertainty" (Environment Canada, 1988). Over time, the impracticality of the approach renders it less easy to use and implement. This approach has been used for several years in the absence of better data with which to assess risks, as is thus in widespread use in various forms.

Disadvantages

The drawbacks are that absolute levels by definition are not site-specific, which means that cleaning up a site to that level will either be overly protective of human health and the environment, or not protective enough. Neither of these outcomes is beneficial: the cost of overprotection is achieved at the expense of having less funds available to address other sites which may pose greater risk. "The more we spend on cleanliness as a moral ideal, the less we have to spend on real health threats." (Bovard, 1989)

Therefore, use of trigger levels implies that health and cost are less important than simplicity. This explains why absolute values are increasingly found to be not scientifically, economically, or politically acceptable.

Examples

The Environment Canada (1988) report contains a detailed evaluation of the methods summarized here.

Ad Hoc Practices: Deciding cleanup levels according to public pressure, perceived risk, or other criterion other than whether the site poses a true hazard. An arbitrary and capricious method which is perceived to be (and is) unfair because the values vary from site to site for reasons other than actual risk to health or the environment. This method has been described by the U.S. Congress Office of Technology Assessment as "no longer acceptable." (Environment Canada, 1988)

National Goals/Standards: Setting the same cleanup standard which applies to all sites. Examples include threshold levels used in The Netherlands (the "ABC" System), France, Alberta, Ontario, and United Kingdom ("Harwell" figures).

Under the "ABC System" (or variations on this method), contaminant levels are grouped in one of three categories (A, B or C). The criteria for each of these categories are outlined below.

A Contaminants present at background or detection limit.

B Contaminants present at "moderate" levels (i.e., requires detailed analysis and some restorative or reclamation procedures may be necessary for agricultural, residential or recreational uses).

C Contaminants present at "severe" levels (i.e., would require corrective measures and restrictive land uses until such time as reclamation techniques lower the contaminant values).

This type of system is used as a general guide to the management of contaminated soils and groundwater.

None of these approaches provides the scientific basis for how these levels were chosen; the Harwell report acknowledges the levels were based on "professional judgment" (Department of the Environment, 1987), as are the others. With the amount of data available today to determine site-specific cleanup values, there is no longer any justification for basing cleanup levels simply on "judgment" as used to be necessary when far less data were available. In addition, these values do not meet most of the criteria set forth in the previous section.

Background Levels: Setting cleanup levels according to existing "background" levels on the assumption that background exposures do not pose a risk. Although seemingly

straightforward, this approach has the following main drawbacks: background levels are rarely known in a given area; background levels for some common substances is zero (such as PCB) which may not be technologically possible to clean up to; and, most importantly, background levels may be above or below levels which are associated with adverse health effects, which means that cleaning up to background levels may not ensure adequate protection of health or the environment in some areas (as is often the case with radon or lead).

Furthermore, it has been determined that the natural levels of inorganic chemicals in particular may differ widely from place to place, such that "at many places worldwide (e.g., FRG, Belgium, The Netherlands, [Australia]), the natural levels of heavy metals in soil exceed concentrations which would require cleanup according to trigger values set by, e.g., the Dutch authorities." (Poels, 1989) The U.S. Congress Office of Technology Assessment has concluded that "cleanup criteria based on background or pristine levels did not make environmental, technical, or economic sense." (Environment Canada, 1988)

Technology-Based Standards: Using the best available technology or best engineering judgment to determine how the site will be cleaned up, regardless of whether there is a hazard posed by contaminants at the site. This can be a very costly criterion if there is little actual risk. The CCREM concluded that "although attractive, technology-based standards did not offer human health and environmental protection comparable to the cost of implementation." (Environment Canada, 1988).

Land Use: Establish cleanup levels and remedial measures according to intended land use, e.g., cover a land farm with paving to convert it to industrial use, or remove/treat the material if it is to be converted to residential use. Although end land use is an important consideration which should be incorporated into decisions about how to clean up the site, the cleanup levels should not be established without being correlated to the actual health risks associated with those levels.

Cost-Benefit: Compare the costs of remediation with benefits in terms of reduced risk to health or the environment. This approach is hard to implement as it is very difficult to measure environmental impacts in dollars or place a monetary value on risk to human health in a way that is acceptable to the public.

B. Relative Approach

This approach derives site-specific cleanup levels according to the exposure conditions at each site, which results in cleanup levels which are protective of health and environment *at that site*. This is the "new generation" of health risk assessment guidelines which are designed to address many of the deficiencies of the trigger level approach.

Advantages

The advantages of the relative approach is that it generates scientifically defensible numbers which are truly protective for that site. This approach is the most cost-effective method of determining cleanup levels since no more and no less is expended than is required to clean up the site to appropriate levels.

In other words, an absolute level may cost $10,000 to develop and result in $2,000,000 of cleanup costs which may have little to do with the actual risks posed by the site. A level based on a relative approach may cost $50,000 to develop, but result in a $1,000,000 cleanup which is protective of health and the environment.

Disadvantages

First, incorporating all the above-mentioned criteria means the system is necessarily complex in terms of the quantity and diversity of data which need to be evaluated. The process of deriving cleanup levels can be time-consuming and expensive in the absence of standard guidelines as to how to develop the cleanup levels, and without a computer-based model or spreadsheet to facilitate making the calculations (although the cost is generally recovered through the development of more defensible levels, as previously discussed). Because cleanup levels will vary between sites, the process will be perceived as unfair until there are consistent guidelines in place for the *process* by which these levels are to be determined.

Examples

Site-Specific Risk Assessment: A formal process of quantifying the probability that adverse effects will occur due to exposure to a chemical. This requires specific guidance regarding indicator chemical selection, estimating exposure, calculating risk for each exposure pathway and route, often in the absence of definitive data.

Existing methods based on the risk assessment approach include the US Army's Preliminary Pollutant Limit Values (PPLV), the U.S. Environmental Protection Agency's Risk Assessment Guidance for Superfund (USEPA, 1989), and the State of California's "Site Mitigation Decision Tree" approach to deriving site-specific Applied Action Levels (AAL) at any abandoned or uncontrolled waste site. The CCREM report (Environment Canada, 1988) concluded that these were the only three strategies which met their criteria for methods to develop soil cleanup levels. Site-specific risk assessments and models which are not based on one of these methods are generally much less rigorous.

Although the methods described here are scientifically stronger than the absolute methods, they are nonetheless cumbersome systems which can be very tedious to use in terms of the time (and therefore cost) required. Calculations for these methods can be readily set up on spreadsheets by individual users, but each features some major drawbacks to its use due to inadequate guidance on input parameters, excessive documentation required to explain the results, length of time required to generate meaningful results, lack of a computer model to ensure consistency in applying the calculations, or other problems. However, each system is under constant review and revision, and is improving over time.

C. Combined Approach

An ideal system for determining cleanup levels should incorporate the best features of both the absolute and relative approaches. The *process* for determining cleanup levels (not the levels themselves) should be uniform and consistent across all sites, and the cleanup values themselves should be site-specific in order to ensure adequate protection of health and the environment at that site. This should result in a method which is both *equitable* and *technically sound*.

Several models exist which are designed to determine soil cleanup levels. Of these, two are more comprehensive than their counterparts. These are evaluated here relative to the criteria set forth for what ideally should be included in establishing cleanup levels.

Examples

AERIS (Aid for Evaluating the Redevelopment of Industrial Sites): This model was developed as a result of the CCREM recommendation to develop a model which would incorporate the best features of the absolute and relative approaches (Environment Canada, 1988). The model is currently under development by Environment Canada; the current

working version (AERIS 2.1) was completed in November 1989 and is expected to be commercially available in early 1990.

However, there is at least one version of AERIS currently in commercial usage, in Australia (Bulman, 1989; SPCC, 1989). This appears to be a modification of one of the earlier versions of AERIS, perhaps 1.0 or 2.0. Only the Australian version of AERIS is evaluated in this paper in detail, as the official Canadian version is still under development and much of the supporting material was not available at this writing.

The Australian version is apparently a modification of the original AERIS model still under development. Unfortunately, based on discussions with the developers of AERIS in Canada, this Australian adaptation of AERIS is not consistent with the original intent of AERIS as established by CCREM or the developers (Ibbotson, 1990; Stelzig, 1990), and there is some resulting confusion as a result of both models working under the same name. Some of the deficiencies of the Australian version are noted here, and distinguished from the original Canadian version where possible to help clarify the differences in the models.

Although AERIS as used in Australia has some strong assets, notably a very thoroughly developed section on soils chemistry, there are major deficiencies associated with use of this model. One major disadvantage is that little or no scientific justification is provided for the input parameters and calculations used to develop site cleanup levels. Only two out of dozens of required calculations were provided in the printout used for a site in Australia, and both were incorrect. Not knowing what calculations were used to estimate risk is a serious deficiency as the validity of the model cannot be assessed without knowing these calculations. As most (if not all) of the calculations are already readily available to the public, this is a curious and unnecessary deficiency. As discussed in the text, hazard and risk assessment is no place for black boxes.

More serious is the lack of justification for the input parameters that are used in the model in Australia. In the printout evaluated for this paper, the bibliographic references cited for dozens of input values are outdated and incomplete, such as "USEPA 1980" and "Australia 1984" for certain health criteria. Not providing a full or current citation is not appropriate for a scientific model, particularly one which attempts to estimate risk to health.

(Note: the developers of the model in Canada assert that the model calculations and input parameters are available in three volumes of documentation in support of the original Canadian version (Ibbotson, 1990). Furthermore, they acknowledge that "some of the environmental fate and toxicological data are constantly being revised by the scientific community and that as a consequence whatever data is included in any model's data base quickly can become stale," and reiterate the importance of using the Canadian model's option to modify most of the parameters with "better, up-to-date, or site-specific data" (Ibbotson, 1990). In using any of these models, it is therefore important to constantly update the model input parameters with current data in order for the model to be valid.)

In trying to verify some of the model results in Australia, it was apparent that there was an inadequate scientific basis for some of the input values used. As an example, several of the ADIs used in the model were based on short-term data in rats, but used to estimate long-term exposure in humans without adequately accounting for the high level of uncertainty in such an extrapolation. In addition, occupational exposure criteria were used for almost all values for public exposure levels, which is widely known not to be appropriate (ACGIH, 1989). (Note: the Canadian developers concur that the use of occupational guidelines is "inappropriate" and they "have no knowledge of any such guidelines being used in AERIS" (Ibbotson, 1990).) Several other deficiencies were noted as well in the Australian model, some quite serious with regard to accurately estimating risk.

Furthermore, the model attempts to generate a level which is of "acceptable risk," explaining in the model documentation that "acceptable risk is defined by toxicological data" (Bulman, 1989). This is inaccurate – determining the acceptability of risk is a value judgment, not a technical question, and for a model to attempt to decide the acceptability of risk is well outside the scope of its purpose. (Note: the Canadian developers concur with

this statement and assert that the original AERIS is used to "derive levels of risk, and that regulatory agencies decide how "acceptable" levels are defined" (Ibbotson, 1990).)

Several pathways and routes of exposure are not included in the Canadian or Australian model, which is a serious deficiency if the purpose of the model is to accurately estimate hazards. Dermal exposure is not evaluated, which can be a significant route of exposure (particularly to children) at many sites. No non-human receptors are directly assessed (wildlife, livestock, fish, vegetation, etc.), nor human exposure to these receptors, thus further underestimating risk at most sites. Several other deficiencies of the model render the results given by the (modified) AERIS calculations of little use in accurately estimating risk, as the model now exists, as it does not give an accurate picture of the complete hazard posed by contaminants at a site.

Finally, the Australian model is extraordinarily expensive, costing up to several thousands of dollars to run what is basically a spreadsheet exercise. Given that neither the scientific basis of the input values nor the calculations themselves are given in the resulting report, in addition to the fact that the model does not address all sources, pathways, and receptors of concern (and thereby underestimates the actual risk), the model is of questionable value at any cost. No cost has been established for the Canadian version of AERIS being prepared for commercial distribution.

Despite these drawbacks, these model deficiencies can be corrected and the model could become very useful in helping to establish soil cleanup levels. It is hoped that when Environment Canada releases the commercial version of AERIS that it be released to the public domain at minimal cost, and with adequate documentation, in order to encourage its widespread use. This in turn will allow improvements to the model over time as the model is applied to an increasing number of sites.

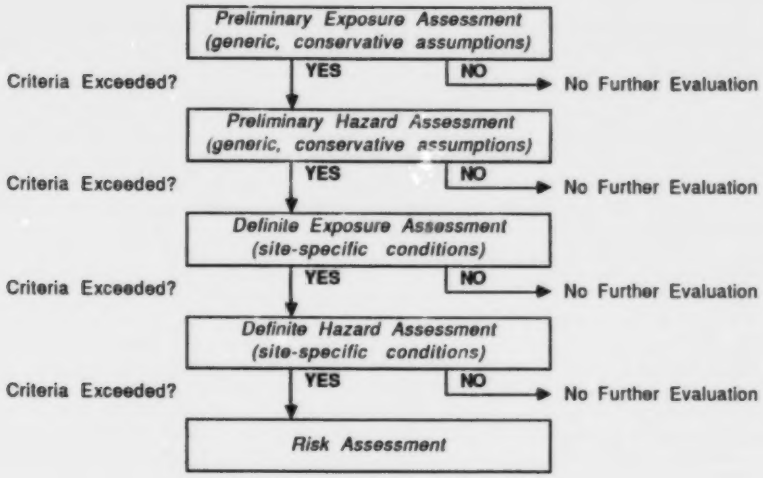
In conclusion, significant differences apparently exist between the current working version of AERIS in Canada vs. the version in commercial use in Australia by the same name, which appears to be based on an earlier version of AERIS. Independent of these differences, serious deficiencies exist in the model in that it does not evaluate all pathways, routes, and receptors of potential concern. *As a result, estimates of risk posed by a hazardous waste site may be underestimated at a site by the AERIS model, perhaps significantly, and the results of neither model are qualified as to the degree of uncertainty or potential underestimation of risk due to not addressing all pathways, routes, and receptors of concern.* This serious deficiency should be corrected before this model is used to help determine cleanup levels at contaminated sites.

HESP: A document entitled "Hazard Assessment of Chemicals in Soil" has been conceived and developed by the European Chemical Industry Ecology and Toxicology Center, and will be published in early 1990 (Poels, 1990). The mathematical modelling component of the document, which is designed to estimate exposure concentrations, is called the Human Exposure to Soil Pollutants or HESP model and is based on an earlier version of the AERIS model (Poels 1989). To AERIS they added several exposure routes and site-specific parameters, resulting in much more accurate soil cleanup values which vary according to final end use of the land (residential, agricultural, recreational, or industrial), as does AERIS.

The HESP model is then expanded into a type of decision-tree framework. The result is a combination of the best aspects of the rationale behind the State of California Decision Tree approach, but computer-based to greatly reduce time and effort involved in calculating the cleanup values.

The HESP evaluation begins with very conservative assumptions for all contaminants and exposure routes (e.g., lifetime exposure). Selective screens are then applied to the evaluation of the site, and those parameters which do not pass the conservative criteria are then evaluated according to more site-specific conditions as appropriate (e.g., actual exposure duration).

The outline of the HESP approach is shown below, which is conducted for each contaminant and exposure pathway of concern:



In HESP, the "hazard assessment" (defined as the estimate of adverse effects which are likely to occur bearing in mind the toxicity of substances and site-specific exposure when these substances are present in soil) is a separate activity from the "risk assessment" which may or may not follow a hazard assessment, depending on its outcome. The results of the exposure and hazard assessments are compared to Maximum Tolerable Exposure Levels (MTELs), which are No Observed Adverse Effect Levels, or NOAELs, modified by an appropriate uncertainty factor. Substances or exposure pathways which result in MTELs being exceeded proceed on to the next level of investigation.

A risk assessment is required for all contaminants and exposure pathways which are judged to pose a potential hazard in the Definite Hazard Assessment, both singly and in combination. The risk assessment is defined by HESP as the assessment of the probability that the potential hazard of a substance in soil is realized under site-specific conditions, and takes into consideration such factors as access to the contaminants, presence of receptors, extent of pollution, etc. (Poels, 1989). In other words, the issue of whether the groundwater is contaminated above drinking water levels (results of the HESP model) remains distinctly separate from the issue of what action should be taken as a result of that fact (which is a sociopolitical decision), provided it is shown that the possibility of exposure exists.

The HESP authors state that the final risk assessment step is a matter of "expert judgment" which is therefore not part of the model, and that the matter of what action is to be taken once the hazards and risks are defined is a sociopolitical judgment. This approach allows the HESP model to collate and reduce the large amount of data required to evaluate a site into some meaningful results, at which point expert judgment is required for the final interpretation of these results, and policymakers can decide what action to take on that interpretation on the basis of sociopolitical concerns.

This in turn allows resources to be used most effectively – the model for assimilating data, scientific judgment to interpret the results according to site-specific conditions which are not reflected in the model, and policymakers (and not scientists) to make the resulting value decisions. Furthermore, the system recognizes that it is not appropriate for the model

to generate figures which are described as being of "acceptable" risk, but to generate enough useful information so that others can make the value determination about the "acceptability" of that risk.

Through this structured approach, the HESP model has reduced much of the time-consuming and tedious nature of risk assessments as currently conducted, without sacrificing accuracy of the outcome. The contaminants of concern are still evaluated in detail, but those that do not pose a health hazard (i.e., are not present above established criteria) fall out at appropriate points in the evaluation process instead of receiving equal attention throughout the entire process of deciding cleanup levels. This greatly reduces the amount of time and effort required for the final risk assessment step.

The model strongly emphasizes the use of measured rather than estimated data, which is appropriate but not often done at a site. It also allows ready evaluation of environmental compartments of concern where contaminants may concentrate. Future plans for HESP are to expand it to include non-human receptors, validate the model, and establish a "relatively inexpensive" PC-based program, including a user manual presenting all formulas and assumptions made in the model (Poels, 1990).

The trial runs of HESP we evaluated reflected a process which meets more of the criteria outlined above than any other current method of determining cleanup levels of which we are aware. If plans for HESP proceed as indicated and the models assumptions are based on sound scientific data and assumptions, it would provide an extremely useful tool for assisting in determining site cleanup levels.

IV. CONCLUSION

As countries adopt and modify methods for deriving site cleanup levels, it is strongly advocated that agencies adopt a soundly scientific approach and develop guidelines that ensure that approach is consistently applied.

This assumes that the primary criterion is protection of health and the environment. If simplicity is the goal of a system to determine cleanup levels, then any one of several systems of "trigger levels" or thresholds may be adopted. However, cleanup levels based on an absolute approach are not scientifically, economically, or politically defensible, and should not be used at any site where any of these criteria are important. Furthermore, adopting an overly simplistic approach to solving a complex problem generally serves to worsen the situation, at hazardous waste sites or elsewhere.

Quickly deriving cleanup levels based on a relative approach can be greatly facilitated by use of agreed-upon criteria for determining cleanup values, consistent risk assessment guidelines to standardize the *process* (i.e., not the levels), a comprehensive set of defensible parameters to be used in conducting hazard and risk assessments, and greater use of computer-based spreadsheets or models to expedite the numerous calculations involved in a thorough risk assessment. Of the available models, the HESP model shows the greatest promise as a model which will fulfill the criteria set forth in this paper. However, it should be remembered that any computer-based model which underestimates risk is not an improvement over a more thorough assessment using simple spreadsheets, particularly where the possibility for serious impacts to health and the environment exists.

V. ACKNOWLEDGEMENTS

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LIGNES DIRECTRICES DU MINISTERE DE L'ENVIRONNEMENT DU QUEBEC SUR LES ANALYSES DE RESQUES

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Important Recent Advances in the Practice of Health Risk Assessment: Implications for the 1990s[1]

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Health risk assessments have been so widely adopted in the United States that their conclusions are a major factor in many environmental decisions. The procedure by which these assessments are conducted is one which has evolved over the past 10–15 years and a number of shortcomings have been widely recognized. Unfortunately, improvements in the process have often occurred more slowly than advancements in technology or scientific knowledge. Recent significant advances for more accurately estimating the risks posed by environmental chemicals are likely to have a dramatic effect on the regulation of many substances. Each of the four portions of risk assessment (hazard identification, dose–response assessment, exposure assessment, and risk characterization) has undergone significant refinement since 1985. This paper reviews some of the specific changes and explains the likely benefits as well as the implications. Emphasis is placed on the improved techniques for (a) identifying those chemicals which may pose a human cancer or developmental hazard, (b) using statistical approaches which account for the distribution of interindividual biological differences, (c) using lognormal statistics when interpreting environmental data, (d) using physiologically based pharmacokinetic models for estimating delivered dose and for scaling up rodent data, (e) using biologically based cancer models to account for the seven or more apparently different mechanisms of chemical carcinogenesis, (f) describing the severity of the public health risks by considering those portions of the population exposed to various concentrations of a contaminant, and (g) reviewing how criteria for acceptable risk have been influenced by the number of exposed persons. The net benefit of these improvements should be a reduction in the uncertainty inherent in current estimates of the health risks posed by low level exposure to carcinogens and developmental toxicants. © 1989 Academic Press, Inc.

INTRODUCTION

Risk assessments can be an important tool for evaluating the potential hazards of human exposure to industrial chemicals. The conclusions of these assessments have, at times, played a major role in many environmental decisions (Ruckelshaus, 1984; Department of Health and Human Services, 1986; Yosie, 1987). The risk assessment

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process has been particularly useful in helping elected officials and the public understand the magnitude of the risks and, thus, has helped reduce unwarranted concern over trivial hazards (Young, 1987). Due to increased emphasis, the fields of toxicology, pharmacokinetics, epidemiology, and molecular biology, as well as others, have made significant progress in improving our understanding of chemical substances (Kroes, 1987; Loury *et al.*, 1988; Schaeffer, 1988; Reynolds *et al.*, 1987). However, not all of these advances have been routinely incorporated into the risk assessment process (OSTP, 1985). The knowledge gained from our experiences in conducting risk assessments, coupled with the scientific advances of the past few years, should dramatically improve our ability to accurately estimate the human health risks of low level exposure to chemicals in the 1990s (Paustenbach, 1989a,b).

Over the past 5 years, more than 250 scientific manuscripts have been published which discuss and critique various portions of the assessment process used to evaluate environmental hazards. As many as 30 of these papers have discussed specific approaches for improving the methodologies used to identify and classify carcinogens, as well as developmental and reproductive toxicants. At least 20 others have addressed the shortcomings of how the risks are estimated for very low doses, and some have proposed alternative methods. Some 80 papers have discussed alternative ways to accurately estimate human exposure to xenobiotics in our air, water, soil, food, and environs (Paustenbach, 1989a). As many as 100 others have generally discussed the process. Further, an increasing number of scientists are investigating ways to better characterize the risks so that regulators, scientists, and the public can fully understand and quantify the magnitude of the risks and reach the best decision on what, if anything, to do about them (Wilson and Crouch, 1987; Covello *et al.*, 1987). The purpose of this paper is to identify and describe some of the scientific advances which have occurred during the past 5 years and to discuss how these advances will change both the way we will conduct health risk assessments and the way society and regulators may view the significance of environmental hazards.

Basic Concepts in Risk Assessment

A risk assessment provides the bridge between research and risk management (Fig. 1). It assembles and interprets all the relevant information for the risk manager. It is a written document in which all the information regarding toxicity, human experience, environmental fate, transport, and exposure should be presented, discussed, and evaluated. The goal of an assessment is to estimate the likelihood of an adverse effect on humans, domestic animals, wildlife, or ecological systems produced by a specific level of exposure to a chemical or physical agent (NAS, 1983).

The risk assessment process has received fairly broad acceptance among members of the public and regulatory agencies, in part, because assessments put the words toxicity, hazard, and risk into perspective (Lowrance, 1982; Yosie, 1987). Regrettably, these words have not always been used correctly either by the lay press or those within the scientific community. Toxicity, as noted by Paracelsus in the 15th century, is an inherent property of all substances. All chemical and physical agents can produce adverse effects (e.g., toxicity) at some dose or under specific exposure conditions (concentration plus duration) (Ottoboni, 1984). Exposure to a particular substance, like benzene, offers the opportunity for injury to occur, and thus exposure poses a

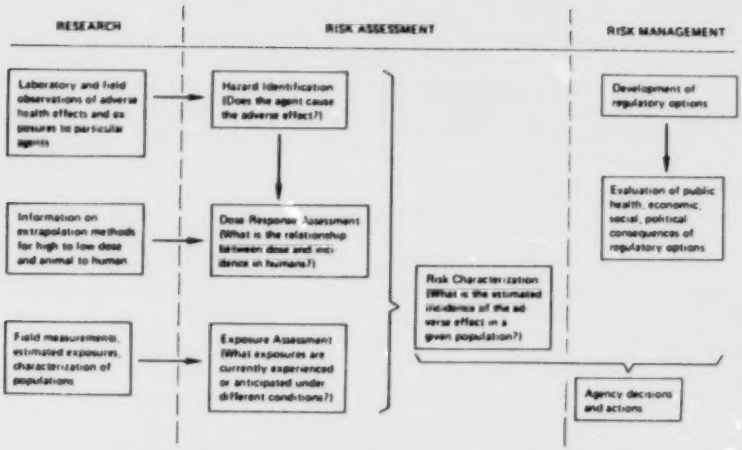

FIG. 1. Elements of risk assessment and risk management (from NAS, 1983).

hazard, such as leukemia. Risk, however, is the likelihood that an adverse outcome, such as leukemia, will occur when a person or group is exposed to a particular concentration or dose for a specific period of time. Therefore, risk is a function of exposure and absorbed dose.

Risk assessments are typically divided into four distinct portions (Fig. 1): hazard identification, exposure assessment, dose–response assessment, and risk characterization (NAS, 1983). The first of the four segments, hazard identification, is defined as the process of determining whether exposure to an agent could cause an increase in the incidence of certain adverse health effects in humans or wildlife. For example, can exposure to asbestos cause mesothelioma in humans? If an analysis of all the data suggests that a chemical can pose a particular hazard, unless the degree of exposure is obviously insignificant, the other steps in the assessment should be pursued. Exposure assessment identifies the intensity, frequency, and duration of exposure and quantifies the degree of uptake (absorbed amount). The differences in the degree of exposure of specific groups within the general population should also be discussed (Lave, 1982; Preuss and Ehrlich, 1987). The next phase, dose–response assessment, addresses the relationship between the external or internal dose of an agent and the incidence or severity of the response, including the estimated response at doses far below those tested. Finally, risk characterization consists of estimating the incidence of an adverse response in a population based on the level of exposure and the results of the dose–response extrapolation. Uncertainties in the assessment, including a discussion of the likelihood that no adverse effects might occur, are addressed here.

HAZARD IDENTIFICATION

Hazard identification is the most easily recognized portion of a risk assessment. It involves characterizing the nature and strength of the evidence of causation (NAS,

1983). Although the question of whether a substance causes cancer, developmental toxicity, or some other adverse health effect in humans is often depicted as a yes or no question, there are few chemical or physical agents for which human data are definitive. Consequently, the bulk of our knowledge about carcinogens and developmental toxicants is based on data obtained in animals, thus introducing some uncertainty about its applicability to humans. As a result, the hazard identification step involves consideration of many factors which affect how we will interpret animal studies (Calabrese, 1983; Barr, 1988; Khera, 1987).

During the 1960s and 1970s, regulatory agencies often reacted spontaneously to consider restricting or banning the use of a chemical when the results of 2-year cancer bioassays indicated that it was carcinogenic (Havendar, 1984). The belief was that nearly all animal carcinogens posed a significant human health hazard. Likewise, during the post-thalidomide years, there was concern about the human hazard posed by chemicals shown to be developmental or reproductive toxicants in animal studies, as well there should have been. Significant strides, however, have been made since then in our understanding of how to identify chemicals likely to pose a significant carcinogenic, developmental, or reproductive hazard to humans (EPA, 1986b,e; Butterworth, 1987; Johnson, 1987, 1988; Hay, 1988; EPA 1988b,c). For example, we now recognize that it is important to understand the genotoxicity of a chemical when evaluating its hazard to humans following low level exposure (Weisburger and Williams, 1986). We have also learned that pregnant animals exposed to very high doses (i.e., maternally toxic) of a xenobiotic are likely to bear pups which have developmental effects, but that these results are not necessarily directly relevant to humans exposed to much lower levels (Johnson *et al.*, 1987).

Carcinogens

Until recently, our approach to identifying carcinogens was straightforward: we conducted 2-year or lifetime studies of rodents and made a determination as to whether the exposed animals exhibited an increased incidence of any tumor type as compared to the control (Haseman, 1985; McKnight, 1988). In cases where an increase in the incidence of a benign or malignant tumor was observed at any dose or in either sex, EPA tentatively classified the agent as one posing a probable carcinogenic hazard to humans. The difference between the carcinogens was considered simply one of carcinogenic and/or mutagenic potency (Crump *et al.*, 1976; Krewski *et al.*, 1984; Barr, 1988). In recent years, fewer scientists are comfortable in stating that all animal carcinogens, more or less, pose a hazard equal to humans. The simplicity of such an approach has shown itself to be inadequate (Havendar, 1984). For example, perhaps as many as eight different mechanisms of action may be involved in producing tumors in treated test animals. Due to our increased understanding of the importance of mechanisms, it is unlikely that the kind of regulatory decisions of the 1980s involving EDB in food, dioxin in soil, Alar and chlordane as pesticides, and saccharin in dietary products will be repeated in the 1990s.

Our early attempts to restrict or ban exposure to all animal carcinogens were impractical and unnecessary (Ruckelshaus, 1984; Ames, 1987). Although it was reasonable for the country to be concerned about the results of early bioassays which showed that numerous chemicals, when administered at the maximum tolerated dose

(MTD), produced tumors in rodents, it appears that we may have often overreacted. Over the past 10 years, we have developed a skepticism about the applicability of these results to humans exposed to doses 1000- to 10,000-fold below those that produced tumors in rodents (Wilkinson, 1988). We have also learned that in many cases the cost of eliminating low level exposure was great and perhaps unnecessary when the resulting decrease in the risk was small. Further, we began to compare the various hazards posed by environmental contaminants to those which are part of the background exposures to carcinogens. For example, the reasonableness of reducing exposure to man-made pesticides to the risk level of 1 in 1,000,000 when naturally occurring carcinogens in our diet probably pose a hazard at least 10,000-fold greater than that due to residual pesticides began to be questioned (Ames, 1983).

Our ability to readily identify those chemicals which pose the greatest hazard has been shown to be less effective than once was believed. Recent work indicates that *in vitro* tests for mutagenicity, which we had hoped would quickly and inexpensively identify all carcinogens, are not as reliable as once thought (Tenant *et al.*, 1987). Our common sense, coupled with a better understanding of the human experience (epidemiology), as well as an awareness of the number and quantity of carcinogens in our diet, has demonstrated that the hazard identification and risk characterization processes are fairly complicated (Ames, 1983, 1989; Ames *et al.*, 1987).

Weight of Evidence

As shown in Table 1, about 8 years ago Squire (1981) recognized that evaluating carcinogens was a complex undertaking. He proposed that one way to rank chemical carcinogens was to consider six factors which he believed would dictate whether a chemical was likely to pose a significant carcinogenic risk to humans. Although his approach, valid and thought-provoking, never seemed to receive wide acceptance, the essence of his views is reflected in the weight of evidence approach presented in the U.S. Environmental Protection Agency *Guidelines for Carcinogenic Risk Assessment* (EPA, 1986e).

Beginning in 1986, a more thorough approach than the prior one was adopted by EPA in an attempt to classify likely human carcinogens. Following a qualitative evaluation, the chemicals were placed into one of five categories based on the "weight of evidence" for carcinogenicity from human and animal studies. The EPA categorization is of critical importance because it usually dictates the nature of the quantitative assessment that ultimately forms the basis for regulatory decisions (Anderson, 1988). The Guidelines state:

> Agents that are judged to be in the EPA weight-of-evidence stratification Groups A and B would be regarded as suitable for quantitative risk assessments. Agents that are judged to be in Group C will generally be regarded as suitable for quantitative risk assessment, but judgments in this regard may be made on a case-by-case basis. (EPA, 1986e, p. 33,996, col. 3)

Chemicals placed in category A or B will normally undergo a quantitative risk assessment carried out by a regulatory agency. Such assessments usually calculate only upper bound estimates of risks and usually depend upon a number of worst-case default options (Anderson, 1989). Consequently, chemicals which are placed in group A or B will usually be regulated so that human exposure is limited to very low levels

TABLE 1

A PROPOSED APPROACH FOR ANIMAL RANKING CARCINOGENS[a]

Factor	Score
A. Number of different species affected	
Two or more	15
One	5
B. Number of histogenetically different types of neoplasms in one or more species	
Three or more	15
Two	10
One	5
C. Spontaneous incidence in appropriate control groups of neoplasms induced in treated groups	
Less than 1 percent	15
1 to 10 percent	10
10 to 20 percent	5
More than 20 percent	1
D. Dose–response relationships (cumulative oral dose equivalents per kilogram of body weight per day for 2 years)*	
Less than 1 microgram	15
1 microgram to 1 milligram	10
1 milligram to 1 gram	5
More than 1 gram	1
E. Malignancy of induced neoplasms	
More than 50 percent	15
25 to 50 percent	10
Less than 25 percent	5
No malignancy	1
F. Genotoxicity, measured in an appropriate battery of tests	
Positive	25
Incompletely positive	10
Negative	0

* Based on estimated consumption of 100 grams of diet per kilogram of body weight. Scoring could also be developed for inhalation or other appropriate routes.

[a] From Squire (1981). Copyright 1981 by the AAAS.

since EPA assessment techniques emphasize the upper bound risk which, more often than not, is generally expected to significantly overestimate the true risks.

The following statements from the Guidelines summarize EPA's weight of evidence scheme for human carcinogenicity (EPA, 1986e):

> The overall scheme for categorization of the weight of evidence of carcinogenicity of a chemical for humans uses a three-step process. (1) The weight of evidence in human studies or animal studies is summarized; (2) these lines of information are combined to yield a tentative assignment to a category and (3) all relevant supportive information is evaluated to see if the designation of the overall weight of evidence needs to be modified. Relevant factors to be included along with the tumor information from human and animal studies include structure-activity relationships; short-term test findings; results of appropriate physiological, biochemical, and toxicological observations; and comparative metabolism and pharmacokinetic studies. The nature of these findings may cause one to adjust the overall categorization of the weight of evidence. (p. 3400)
>
> The agents are categorized into five groups as follows [descriptions deleted]:
>
> Group A—Human Carcinogen
> Group B—Probable Human Carcinogen

Group C—Possible Human Carcinogen
Group D—Not Classifiable as to Human Carcinogenicity
Group E—Evidence of Non-Carcinogenicity for Humans

The EPA categorization system (EPA, 1986e) was adopted from the International Agency for Research on Cancer (IARC) supplement 4 (IARC, 1982). The EPA approach bifurcated the inadequate evidence category labeled Category E in the IARC criteria to include three additional categories: Category C for chemicals as possible carcinogens in humans, D for those which have inadequate testing, and E to indicate negative evidence.

It has become clear to EPA and the scientific community that it is again time to revise this scheme as evidenced by EPA's "intent to review" the carcinogen risk assessment guidelines (EPA, 1988d). At least three improvements in our understanding indicate that an updating is in order: (a) in 1987, IARC revised its scheme to restrict the use of the term "probable" human carcinogen, (b) EPA's weight of evidence approach has had difficulty accounting for epidemiology data and weak carcinogens, and (c) the scheme does not account for the different mechanisms of action of the nongenotoxicants, promoters, and other noninitiators. The misuse of both the IARC and EPA lists have recently been addressed (Barnard *et al.*, 1989).

Considering Biologic Criteria

Over the last 5 to 10 years, the weight of evidence has become sufficiently convincing for a significant fraction of the scientific community to agree that there could be at least eight major classes of chemical carcinogens: genotoxicants, promoters, cytotoxic liver carcinogens, mitogenic liver carcinogens, peroxisomal proliferating/mitogenic liver carcinogens, cytotoxic kidney carcinogens, cytotoxic bladder carcinogens, and solid-state carcinogens (Butterworth, 1987; Reynolds *et al.*, 1987; Andersen, 1988). The significance of acknowledging that carcinogens can act through one of several mechanisms is that a number of these processes would be expected to have a threshold dose below which no cancer risk would be likely (Butterworth and Slaga, 1987; Wilson, 1989). If this view becomes agency policy, the standard regulatory approach which involves use of the multistage model and its bounding technique would not be appropriate for estimating the health risks posed by a significant number of chemical carcinogens.

Adoption of more complex guidelines may also result in greater pressure to consider mutagenicity, genotoxicity, species and gender specificity, metabolism, tumor type, route of administration, disposition among tissues, tumors which occur only at the maximum tolerated dose, the no observed effect level (NOEL), pharmacokinetics, physiologically based disposition models, mechanism of action, and other factors when deciding how to estimate the risk at low doses. From these and other data, we would have a reasonable degree of certainty how a chemical is likely to act at low doses or whether it acts through a combination of mechanisms (Hay, 1988). Armed with this information and using a weight of evidence approach, scientists would be equipped to properly conduct the hazard identification and dose–response steps.

Certainly, one aspect of hazard identification that will receive greater attention in the coming years is the study of specific tumor types and whether one type is more

likely to pose a human health hazard than another. It seems fairly clear that not all rodent tumors pose the same hazard to humans. For example, numerous national and international commissions have attempted to understand the relationship, if any, between an increased incidence of mouse liver tumors (especially, those that occur late in the rodent's lifespan) following chronic exposure to a xenobiotic and the likelihood that the chemical poses a significant human hazard (Doull *et al.*, 1983). The significance of rodent tumor types in predicting the potential human health hazard is evidenced by recent scientific assessments and the regulatory actions, which support a threshold, e.g., goitrogens (Paynter *et al.*, 1988) and unleaded gasoline (Short *et al.*, 1986; Charabonneau *et al.*, 1988).

It is quite likely that there will be a continuing interest in how to interpret tumor data collected in rodents. For example, results of the NCI bioassays indicate that many chemicals which increase the incidence of a given tumor type are frequently inhibitors of another tumor type (when compared with control animals). Many of the chemicals which we have classified as a carcinogen because of an increased incidence of one tumor type would not be considered carcinogenic if total tumors were used as a criterion for classification. In addition, frequently the incidence of total tumors or a specific tumor will be less in the lowest test group than that observed in the controls. This is known as hormesis, a process wherein exposure to an agent which is expected to cause an adverse effect actually yields a beneficial result. It is believed by some to be a result of the activation of compensatory biologic mechanisms due to challenging (exposing) the animal to a xenobiotic (Calabrese, 1983). Hormesis is of interest to biologists since humans are typically exposed to levels 100- to 10,000-fold below the lowest dose tested in animals. This phenomenon places into question the reasonableness of the "one molecule theory," which justifies the assumption of linearity of response at very low doses. For example, animals exposed to dioxin, one of the most potent animal carcinogens, had a lower incidence of the tumor type of interest at the lowest dose tested than that observed in the controls (Kociba *et al.*, 1978).

During the 1980s, we learned (through experience) not to place a high degree of confidence on extrapolating the results of animal studies directly to humans. A noteworthy case is the phenomenon of male rat nephrotoxicity which has been shown to be induced by a number of different hydrocarbon components of unleaded gasoline (UG) (Alden, 1986; Short *et al.*, 1986). Male rat nephrotoxicity is considered unusual by the research community because other mammals, including female rats and both sexes of mice, guinea pigs, dogs, and monkeys, are resistant to kidney injury as a result of exposure to hydrocarbons (Stone *et al.*, 1987). Even more interesting was the observation of kidney tumors in male rats (Kitchen, 1984). In studies attempting to understand this response, it was shown that acute exposure to UG exacerbated the spontaneous protein resorption of the proximal convoluted tubule epithelial cells. An early indicator of toxicity was the formation of hyaline droplets, while advanced stages demonstrated chronic nephrosis (Kanerva *et al.*, 1987). Ultimately, the binding of components of UG to the protein α-2-macroglobulin (α2G) was shown to influence the toxicity and was identified as unique to the male rat kidney (Charbonneau *et al.*, 1988).

Although regulatory action is still being debated, it has been difficult for agencies to neglect that neither the opposite rat gender nor either sex of any other species tested exhibited this response. Since the α2G protein has been identified in the male rat kidney but it is not present in the other tested groups, the evidence seems convincing

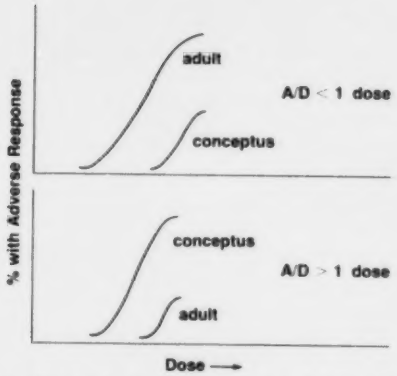

FIG. 2. A part of hazard identification for developmental toxicants is to evaluate the relationship between adult (A) and developmental (D) effective doses. In the plot where A/D is less than one, toxic effects are seen in the pregnant animal at doses lower than those which adversely affect the conceptus. In contrast, where the A/D ratio is greater than one, the conceptus is much more sensitive to the effects of the chemicals than the mother. The latter category of chemicals is of particular concern. Reprinted from Paustenbach (1988), *Journal of Toxicology and Environmental Health* **23**(1), published with permission from Hemisphere Publishing Corp., Washington, D.C., New York.

that the response to UG components is not only gender but also species specific. This example illustrates how our continued efforts to understand the mechanisms of tumorigenesis and the molecular basis of species specificity is likely to improve the quality of risk assessments.

Developmental and Reproductive Toxicants

The identification of a chemical which is likely to be a developmental or reproductive toxicant in humans is as complex as the identification of likely human carcinogens (Schardein, 1987). Not only is the slope of the dose–response curve and the identification of a NOEL important, but the timing of the exposure as well as the type and severity of the effect needs to be considered (Khera, 1987; EPA, 1986b; Johnson, 1988). Unfortunately, we know little about the various biological mechanisms of action for developmental or reproductive agents. However, we do know that virtually every substance, when administered at the correct time to the mother, will induce some type of adverse developmental effect on the fetus if the dose is sufficiently high. This observation is known as Karnovsky's law (Karnovsky, 1965). It has dictated that criteria beyond the classic toxicologic endpoints for developmental effects need to be used to identify chemicals which pose a human health hazard (Johnson, 1987, 1988; Wang and Schwetz, 1987; Hart *et al.*, 1988; Johnson, 1989).

The desire to identify reproductive and developmental toxicants has resulted in improved test procedures, and we are currently trying to identify new tests and methods for interpreting existing data so that we can improve our assessment of these classes of chemicals (EPA, 1986b, 1988b,c). A prime objective is to identify those chemicals which are phase-specific toxicants and those which affect the offspring at doses that do not cause adverse effects on the mother (Fig. 2). The FDA's Segment II

TABLE 2

A PROPOSED APPROACH FOR EVALUATING TERATOGENICITY[a]

Factors	Points
1. No. of animal species affected with teratogenic response	
Two or more species	30
One species	15
One positive species with one or more negative species	10
2. Relevancy of route of administration	
Relevant route, similar mode (e.g., gavage vs. diet) regarding human exposure	25
Relevant route, different mode regarding human exposure	15
Route unrelated to human exposure	0
3. Multiplicity and nature of developmental effects	
Malformations with or without changes in fetal body weight or resorptions	30
Minor alterations with or without changes in fetal body weight or resorptions	20
Effect on fetal body weight or resorptions without malformations or alterations	10
4. Distribution of developmental effects among litters	
Multiple litters with one or more major effects common to all litters	25
Malformations or alterations significant only on composite basis	15
Single litter response	5
5. Extensive number of litters or fetuses per litter being affected	
Present	5
Absent	0
6. Rare vs. common malformation	
Rare malformation, large increase in prevalence	20
Common malformation, large increase, or rare malformation marginal increase	10
Common malformation, marginal increase	5
7. Ratio of embryotoxic dose/maternal toxic dose	
<0.9	30
0.9 → 1.1	15
>1.1	5

[a] From Wang and Schwetz (1987).

test protocol seems to be adequate for identifying developmental hazards since the dam is exposed throughout the key portions of the pregnancy (Johnson *et al.*, 1987). One method for selecting substances which are likely to be a developmental hazard in humans is to identify those chemicals which affect the fetus at doses where no adverse effects occur in the dam. This approach focuses on the relationship between the dose which produced slight adverse effects on the mother or adult (*A*) and the dose which produced adverse effects in the developing fetus (*D*) (Johnson *et al.*, 1987). This *A/D* ratio, when calculated from the data obtained in Segment II tests, appears to be effective at identifying those substances likely to pose a significant human health hazard (Johnson, 1988). Although the approach has some shortcomings, it should be considered one of several important criteria (Khera, 1987; Paustenbach, 1988). Other approaches based on a ratio of the LD_{05} or LD_{50} have been suggested for ranking developmental toxicants, but these have been shown to have too many flaws to be useful (Fabro *et al.*, 1982; Khera, 1987).

Wang and Schwetz (1987) have also proposed a ranking scheme (Table 2) for developmental toxicants which considers not only the *A/D* ratio but six other factors: the

number of species affected, relevancy of the test route, multiplicity and nature of effects, distribution of effects among litters, number of fetuses per litter affected, and rare vs common malformations. Such a scheme allows regulators to differentiate between the public health hazards posed by such diverse developmental toxicants in animals as coffee, thalidomide, ethylene oxide, aspirin, and Bendectin (Johnson, 1989). These and other approaches which can help us separate the "minnows from the whales" should be useful in sorting out those chemicals likely to produce adverse effects on fetal development as well as helping us set priorities regarding those chemicals to regulate or study (Hart *et al.*, 1988; Kimmel and Gaylor, 1988).

These observations, en masse, suggest that we have come a long way in our understanding of the potential pitfalls of a simple "yes or no" approach to hazard identification for carcinogens and developmental toxicants. Fortunately, scientists and regulators have begun taking advantage of the scientific insight gained during the last 5 years when making decisions regarding these types of chemicals (Reynolds *et al.*, 1987). The proposed regulatory actions on dioxin, unleaded gasoline, NTA, goitrogens, methylene chloride, and some other chlorinated hydrocarbons indicate that agencies are prepared to depart from traditional approaches when evaluating rodent carcinogens. The care which agencies have demonstrated in dealing with lead, coffee, the glycol ethers, and many other agents suggests that equal care is being applied to the developmental toxicants. In short, the hazard identification segment of risk assessment may have grown out of its formative years (Von Wittenau, 1987; Wilkinson, 1988).

EXPOSURE ASSESSMENT

Since 1985, there has been growing sentiment that exposure assessment is the segment of risk assessment requiring significant improvement (Paustenbach *et al.*, 1986; EPA, 1986d, 1988f). The objective of the procedure is to estimate the amount of a substance which is taken up or absorbed by humans following exposure via multiple routes (NAS, 1983). It is a challenging task to estimate the likely absorbed dose of a chemical, especially if one considers all the potential sources of exposure such as food, water, air, and soil. The process is particularly complex when factors such as environmental degradation and accumulation, ingestion of contaminated soil and foliage by cattle, deposition rate of particulates, dermal uptake, biomagnification, pharmacokinetics in humans, exposure schedule, and the dietary changes that occur over a lifetime are considered (Paustenbach, 1989a). Nonetheless, with the advent of personal computers and increasing amounts of research aimed at quantifying certain exposure parameters, an accurate description of the uptake of chemicals by humans should be a manageable task (Lippmann and Thurston, 1988).

Exposure is dependent on the chemical's concentration in a particular media. To estimate the distribution of a substance in the environment, it is important to understand its physical and chemical properties (Thibodeaux, 1979; Beck *et al.*, 1981; Cairns *et al.*, 1978; Moghissi *et al.*, 1980). With these data, and some knowledge of the source, equations can be utilized to describe the emission rate, transport, and degree of exposure (EPA, 1986d). Although direct measurement is always better, environmental concentrations are often too low to measure so they must be estimated through modeling (Haque, 1980; Conway, 1982).

In most risk assessments, human exposure usually occurs as a result of inhalation of dusts and vapors, dermal contact with contaminated soils and dusts, and ingestion of contaminated food, water, or soil (Kimbrough *et al.*, 1984; Hawley, 1985; Paustenbach *et al.*, 1986). Interestingly, recent research has shown that indirect routes of exposure such as the ingestion of meat and milk contaminated by particulate emissions falling onto grass and soil with the subsequent ingestion by dairy cows, will often be a more important route of human exposure than the inhalation of the particles (Fries, 1982, 1987; Fries and Jacobs, 1986; Fries and Paustenbach, 1987, 1989). Exposure assessments have become rather complex as our understanding of the various factors has increased. For example, to accurately estimate the uptake of a substance by humans due to the emission of airborne particulates, such factors as (a) particle size, (b) deposition velocity, (c) fine particle enrichment, (d) retention on plant surfaces, (e) transport and binding to soil, (f) bioavailability, (g) environmental degradation, (h) biologic half-life in cows, (i) biomagnification, (j) soil-to-plant ratio, and (k) farm management practices, to name a few, should be considered (Fries and Paustenbach, 1989).

During the last decade, it was clearly shown that the physical and chemical properties of a molecule dictate its transport through environmental systems and its ultimate fate in the environment (Thibodeaux, 1979; Beck *et al.*, 1981; Bergman *et al.*, 1986; Woltering and Bishop, 1989). Accordingly, these properties have a direct bearing on the risk to the exposed human population. For example, the potential for biological magnification can be roughly approximated by a chemical's octanol/water partition coefficient (Spacie and Hamelink, 1985). It can be expected that during the 1990s, estimates of human exposure and the distribution of a chemical will be validated using various exposure models (MacKay, 1985). For example, using our understanding of fugacity, information on the pharmacokinetics of the molecule in living systems, and the environmental half-life, we can often predict with confidence the uptake by humans via various pathways (Travis and Hattemer-Frey, 1988b).

One of the most important developments of the 1980s was a recognition of the potential for indirect and multipathway exposure to xenobiotics. For example, it has been shown that the human uptake of nonvolatile emissions from incinerators due to contamination of the food chain can produce risks 200- to 500-fold greater than that due to inhalation—the direct route of exposure (Stevens and Gerbec, 1988).

To date, only a few risk assessments have mathematically accounted for the many degradation and accumulation processes which will occur over the 70 years of potential human exposure considered in most analyses. For example, the effect of environmental half-life on the anticipated lifetime dose has been illustrated for exposure to TCDD in soil (Paustenbach, 1987). Using exposure assumptions for oral, dermal, and inhalation exposure, it was shown that—if the half-life at the soil surface was 1 year, the soil concentration was 100 ppb, and the oral bioavailability was 30%—the maximum anticipated average lifetime daily dose was 0.14 pg/kg/day for 70 years of exposure. In contrast, if the half-life of TCDD was 12 years, the average dose was shown to increase to 1.6 pg/kg/day (about 10-fold greater).

A relatively new factor to be considered in exposure assessments is the bioavailability of a substance in various environmental media. Most risk assessments of the 1960s and 1970s erroneously assumed that all substances were 100% absorbed in the gastrointestinal tract and between 10 to 100% were absorbed through the skin. Research of the past 5 years has shown that the systemic absorption of chemicals through inhala-

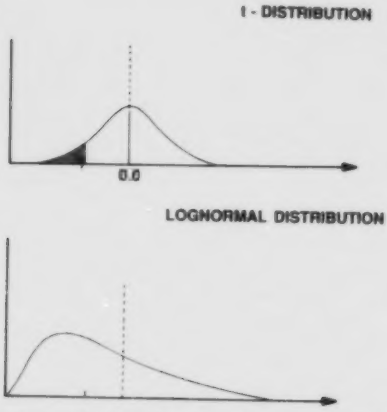

FIG. 3. The lognormal and normal distributions. Nearly all environmental sampling data will have a lognormal distribution and this must be considered in the statistical analyses of the data.

tion, ingestion, and the skin varies with the type of media, e.g., bioavailability, and that it is chemical specific. For example, the oral bioavailability of dioxin on soil has been shown to be affected by the media, time since contamination, concentration in the media, particle size, and co-contaminants (Paustenbach *et al.*, 1986). Specifically, oral bioavailability for TCDD on soil ranges from 0.05 to 40% (Umbreit *et al.*, 1987; McConnell *et al.*, 1984; Shu *et al.*, 1988a). In contrast, the oral bioavailability of fly ash has been reported to be 0.1 to 3% (Van den Berg *et al.*, 1983, 1985, 1986, 1987). The same factors probably affect dermal bioavailability (Poiger and Schlatter, 1980; Shu *et al.*, 1988b).

One shortcoming which has been prevalent in most exposure assessments of environmental contaminants is the failure to recognize that the concentration of contaminants in soil, water, air, and food data are usually lognormally (Fig. 3), rather than normally distributed (Gilbert, 1987; Sielken, 1987b). Accordingly, it is important to apply statistical procedures which account for this phenomenon by calculating geometric mean (GM) and geometric standard deviations (GSD) (Liedel and Busch, 1985; Rappaport and Selvin, 1987; EPA, 1988f). The use of lognormal statistics, where appropriate, is critical because it prevents a single or a few high values from dominating the results and data interpretation. Lognormal statistics also account for the significance of a large number of samples near the limit of detection (LOD). For example, depending on the percentage of samples at the LOD, values of 1/2 to 1/20th the limit of detection can be used in the analyses rather than a value of zero or the limit of LOD. Such analyses can significantly affect the conclusions of a study. For example, in an assessment of workers exposed to the glycol ethers, nearly 70% of the personal samples for ethoxyethanol acetate were below the limit of detection (LOD = 1 ppb). The mean was 250 ppb and the SD was 80, but the GM was only 20 ppb and the GSD was 4.8 (Paustenbach, 1988). Reliance on the mean and standard deviation would have incorrectly portrayed the severity and pervasiveness of the health hazard.

Another major shortcoming of exposure assessments of the past 10 years has been an inordinate emphasis on so-called "worst case scenarios" and "maximally exposed individuals (MEI)." In an effort to ensure that the potential human exposure to an environmental contaminant was not underestimated, extreme situations have often been hypothesized wherein individuals were continuously exposed throughout their lifetimes to the maximum plausible amounts of a substance via all routes of exposure (Maxim, 1989). Although such an approach may be a reasonable "screening assessment" used to dismiss insignificant hazards, these analyses should not be depicted as an estimation of the plausible level of human uptake (Maxim and Harrington, 1984; Finkel and Evans, 1987; Nichols and Zeckhauser, 1988; EPA, 1988f; Maxim, 1989) since the result can represent the risk of 1 in 1,000,000 persons rather than a "typical" highly exposed person.

Predictably, worst case assessments will usually not describe the bulk of the exposed population and will often overestimate even the most exposed person. For example, many attempts to describe the MEI have been based on an assumption that the same person who is a 95th percentile eater of fish was also prone to ingest dirt as a child (95th percentile), reside in the most highly exposed residential area (99th percentile), and eat only vegetables grown in his private (contaminated) garden (95th percentile). A more accurate and reasonable approach to estimating the dose for the MEI is to select the single 95th percentile parameter responsible for giving the highest risk rather than assume that the same person is at the 95th or 99th percentile for three or more parameters (Tollefson, 1989). As recently noted by the EPA (1988f),

> A legitimate use of worst-case scenarios is to determine if the exposure or risk is low enough even at this extreme so as to dismiss concern for this scenario. It is *not* legitimate to use a worst-case scenario to prove that there in fact exists a concern in a real population. In constructing a worst-case scenario, the assessor has usually added assumptions or used particular data points that bring into question whether the scenario actually represents the real world. If the exposure or risk value estimated by a worst-case scenario is high enough to cause concern, the assessor must reevaluate the parameters used and perform reality checks before deciding a problem really exists. *It is* critical that the results of a worst-case individual scenario are not immediately applied to an entire population, since in almost all cases this will result in a substantial overestimate of a potential problem.

One such assessment which seemed to overestimate the risks to the MEI evaluated the potential hazards posed by dioxin (TCDD) emissions from a municipal waste incinerator (EPA, 1988e). The assessment (scenario 2 in the document) involved a hypothetical person who (a) lived on a farm within 1 mile of the incinerator for 70 years, (b) ingested a significant amount of all consumed fish (10%) from a pond on the farm, (c) ingested an inordinate amount of soil and dust as a child, (d) inhaled contaminated dust from the soil, (e) gardened regularly, during which time he had frequent dermal contact with the soil, (f) ingested a significant amount of vegetables (50% of all consumed) grown in the contaminated soil, (g) ingested a significant amount of dairy products (40% of all consumed) and meat (44% of all consumed) from animals raised on the farm, and (h) regularly ingested and bathed in water from the contaminated pond. It was assumed that the person spent 80% of his time on the farm and lived there for 70 years. Although such an exposure scenario is arguably plausible, it is clearly extreme. At best, it might apply to a handful of persons since few farms are located close to municipal waste incinerators. It is hoped that most persons would agree that risk managers need to be presented with an analysis of the

TABLE 3

ESTIMATED EFFECTS OF COKE OVEN EMISSIONS ON U.S. POPULATION[a]

Exposure to benzene soluble organics (micrograms per cubic meter of air)[b]	People in exposure group (thousands)	Lifetime probability of lung cancer[c]	Increase in lung cancer due to coke oven emissions	Number of lung cancer deaths per year due to coke oven emissions
4.5	13,900	0.0335	6.37×10^{-4}	125.0
5.5	1,034	0.0344	1.49×10^{-3}	22.0
6.5	54	0.0362	2.33×10^{-3}	1.8
7.5	8	0.0360	3.18×10^{-3}	0.4
8.5	2	0.0369	4.02×10^{-3}	0.1
10.9	2	0.0389	6.04×10^{-3}	0.2

Source: Adapted from Environmental Protection Agency, Carcinogen Assessment Group, "Preliminary Report on Population Risk to Ambient Coke Oven Exposures" (EPA, March 1978), p. 14.

[a] Estimated using the Weibull probability model.

[b] Background level assumed to be 3.75 micrograms per cubic meter of air.

[c] Lifetime probability 0.0329 at background exposure level.

Note. This table represents one method for presenting exposure, risk, and population data. Such an approach gives risk managers all the important information needed to make the difficult decisions about where to best allocate limited resources, rather than focus only on the maximally exposed individual (MEI). Reprinted from Lave (1982), *Quantitative Risk Assessment in Regulation*, The Brookings Institution.

likely risks for the majority of the exposed population, as well as the number of persons exposed to various high levels (see Table 3). In short, the repeated selection of such worst case assumptions results in estimates which are beyond worst case, and instead, are implausible and of questionable use to risk managers (EPA, 1988f).

Most scientists engaged in risk assessment recognize that the purpose of estimates based on extreme assumptions is to evaluate whether even under such unlikely settings, a significant risk could be present. If the analysis shows no significant hazard, efforts can be directed to another problem. These are often called screening assessments: a technique used to quickly identify and dismiss insignificant hazards. However, risk estimates from such assessments are often placed in the hands of the public, citizen's groups, or regulatory agencies that do not enjoy the same level of understanding about their underpinnings or the intent. Not surprisingly, these groups have been alarmed to learn that such assessments can predict that as many as 10 in 1000 persons who live on farms near an incinerator may die prematurely due to cancer as a result of the presence of dioxin in the fly ash.

In an attempt to develop analyses which are more useful and scientifically defensible than those based on worst case assumptions, several new approaches to estimate exposure within a diverse population have been developed (Bogan and Spear, 1987; Anderson, 1987a). One goal of these approaches is to encourage characterization of the various exposed subgroups. The techniques allow populations to be described in a more fair and complete manner. For example, a better way to describe the risks for a group of 10,000 persons who live within 2 miles of a proposed incinerator would be to characterize them in the following manner: For the particular incinerator which was evaluated, 9500 persons may be exposed to 0.5 to 5.0 fg/kg/day of dioxin equivalents during their lifetime, 490 persons to 5.0 to 25.0 fg/kg/day, and fewer than 10

TABLE 4

THE BEST ESTIMATE (BASED ON THE WEIGHT OF EVIDENCE) AND SOME FREQUENTLY CITED RANGES FOR PARAMETERS USED IN EXPOSURE ASSESSMENT[a,b,c]

Parameter	Best estimate	Range of values
Uptake of air by typical adult	12 m^3/day	10 to 25 m^3/day
Ingestion of tap water by typical adult	1.2 liters/day	0.8–2.5 liters/day
Ingestion of dust and soil by typical toddler (ages 2–6)	25–40 mg/day	25 to 10,000 mg/day
Ingestion of dust and soil by typical adult (ages 8–80)	5–10 mg/day	10 to 500 mg/day
Airborne dust in a neighborhood with a few unpaved roads	200 $\mu g/m^3$	50 to 20,000 $\mu g/m^3$
Freshwater fish ingestion by the average midwesterner	10 g/day	6 to 300 g/day
Ingestion of tomatoes by the average American	30 g/day	10 to 200 g/day

[a] The values for the best estimate are based on the author's review of the literature and his evaluation of the currently available information.

[b] The range of reported values is based on the author's review of approximately 60 risk assessments of major sites or settings. These values are not intended to represent, for example, the 5th and 95th percentile person nor are they necessarily considered credible. Instead, the goal is to illustrate the variability in exposure parameters used by the various scientists conducting risk assessments.

[c] The U.S. Environmental Protection Agency's *Exposure Factors Handbook* (1989) is a useful resource.

persons to levels of 25 to 250 fg/kg/day. The plausible upper bound individual cancer risk for these groups is 1 in 100,000, 1 in 1,000,000, and less than 1 in 10,000,000, respectively; levels of risk similar to eating 1 peanut butter sandwich each week for 70 years or the chance of being struck and killed by lightning during one's lifetime. Furthermore, it is possible that due to dioxin's mechanism of action in humans, no additional risk may be present of any of these levels.

New and more complex exposure models will certainly be developed in the 1990s and these should go a long way in helping us do a better job at estimating and characterizing risk. In their paper, Bogan and Spear (1987) estimated the range of values for water ingestion for the entire population using techniques which would be applicable to other parameters. Their approach incorporated both uncertainty and interindividual variability. It also accounted for a number of factors which influence uptake, including age, eating patterns, lifestyle, and personal physiological parameters, and other factors, such as respiration rate, skin surface area, body mass, cardiac output, water consumption, fat content, skin absorption, and exposure to breast milk. Although such a rigorous analysis may not be necessary to describe each of the 30 to 40 parameters needed to estimate exposure due to, for example, emissions from an incinerator, it clearly offers an approach which can be applied to the most important routes of exposure in a given analysis.

A good deal of effort has been expended in recent years to identify the range and best estimate of values to be used in exposure assessments (EPA, 1989). As shown in Table 4, in light of the fairly broad range of some of the values, most analyses should be based on the best estimate of a specific exposure parameter rather than repeatedly adopt the highest one. To always use the most conservative value would yield implausible results. By evaluating the statistical distribution of reasonable values for each of the various parameters, it is then possible to estimate the level of exposure for different segments of the population. Within just 2–3 years, such approaches to estimating exposure will be used routinely and they will give managers the informa-

tion needed to make better and more defensible decisions. Already, a computer program has been developed and is available to perform such uncertainty and sensitivity analyses for exposure parameters which are either normally or lognormally distributed (Palisade, 1988).

DOSE–RESPONSE ASSESSMENT

Like hazard identification and exposure assessment, significant advancements have been made over the past decade, and particularly since 1985, in our understanding of the strengths and weaknesses of dose extrapolation models and approaches. The dose–response segment of a risk assessment is the process of characterizing the relationship between the dose of an agent and the anticipated incidence of an adverse health effect in an exposed population (Preuss and Ehrlich, 1987). The bulk of our knowledge about the dose–response relationship is based on data collected in animal studies (usually rodents) and theoretical precepts about what might occur at lower doses. Therefore, scaling up animal data to humans is a part of the dose–response assessment. Estimating the risk to humans following chronic exposure to low doses can be particularly difficult since laboratory animals are usually exposed to concentrations which approach toxic levels, while humans are normally exposed to concentrations 1/100th to 1/1000th the no observed effect level in rodent bioassays.

One method for estimating the low-dose response is to use safety or uncertainty factors (Dourson and Stara, 1983; Krewski *et al.*, 1984). For most chemicals, including pesticides, uncertainty factors of about 100 have been applied to the chronic animal NOEL to estimate the acceptable level of human exposure for noncarcinogens (Dourson and Stara, 1983). This approach assumes that no adverse effects will be seen in humans if the dose resulting from exposure is a fraction of the dose which produced no adverse effects in animal tests. This scheme has been used to estimate safe levels of human exposure to carcinogens, developmental toxicants, and systemic toxicants since the 1940s (Stokinger, 1977). An assumption inherent in the use of safety factors is that a threshold dose exists below which no toxic effect will occur. For some chemicals, particularly genotoxic carcinogens, it has generally been agreed that the threshold concept may not be valid (Perera, 1984). Conversely, the uncertainty factor approach may well be appropriate for nongenotoxic carcinogens (Weisburger and Williams, 1986; Butterworth and Slaga, 1987; Swenberg *et al.*, 1987).

Cancer Models

Historically, between 1940 and roughly 1960, there was a general belief that carcinogens and developmental toxicants, like other toxic agents, had a threshold dose below which their adverse effects would not be observed, irrespective of the size of the exposed population. Although it is still believed that developmental agents have a threshold, the concept that carcinogens may pose a risk no matter how small the dose was first proposed in the 1960s. The classic paper by Mantel and Bryan (1961) described an approach which assumed that every dose posed a risk but that a virtually safe dose (VSD), too low to be of concern, could be identified. This conceptual approach appealed to regulatory agencies because of its conservative, e.g., health protective, underpinnings and some evidence that even relatively small doses of ionizing

radiation appeared to pose a cancer hazard. Soon thereafter, for regulatory purposes, most human exposure to chemical carcinogens was assumed to present a finite incremental cancer risk, and this was accommodated in several models which were later developed (Crump *et al.*, 1976; Crump, 1981). From this regulatory philosophy evolved the widespread use of mathematical models which attempted to calculate excess lifetime cancer risk for humans based on dose–response curves obtained in animal bioassays. These have dominated health risk assessment throughout the 1970s and the 1980s, even though they carried a warning that the risks estimated by such models "are unlikely to be higher but could be considerably lower and perhaps zero" (OSTP, 1985).

Beginning in the early 1980s, it became clear to an increasing number of scientists that the results of low-dose extrapolation models might well be seriously overestimating the likely cancer hazard due to exposure to environmental chemicals. Vernon Houk, the Assistant Surgeon General of the United States and the head of the Agency for Toxic Substances and Disease Registry (ATSDR), has claimed that the results of the multistage model and its predictions of the cancer risks have been inconsistent with epidemiology data for numerous chemicals (Houk, 1988). He and others have noted, for example, that model estimates of the cancer hazard posed by occupational exposure to ethylene dibromide grossly overestimated the actual cancer risk (Havendar, 1984). He believes that similar inconsistencies between the epidemiology data and the dose–response model estimates have been demonstrated for other chemicals, including saccharin, formaldehyde, trichloroethylene, and chloroform (Houk, 1988). Others have argued that the epidemiology data cannot be used to refute the multistage model due to the small sample sizes inherent in most human studies and the uncertain levels of human exposure (Hertz-Picciotto *et al.*, 1988; Silbergeld, 1988b).

Criticisms of Models

The problem with the common extrapolation models such as the multistage, Weibull, logit, or one-hit is that they only evaluate one parameter (the slope of the dose–response curve) and cannot account for numerous biological factors. They have even been shown to be poor tools to evaluate potency. Although these models have been used by regulatory agencies to identify the most potent carcinogens and rank them; even this application has been shown to be deficient due to the dose selection methodologies used in bioassays (Haseman, 1985; Reith and Starr, 1989). Specifically, the typical NCI/NTP chronic bioassay with rats or mice often uses 50 animals per dose. Bioassays in the published literature often used fewer than 50 animals and only rarely has the sample size been greater than 50. Thus the potential range of tumor incidences which may be analyzed with the multistage model is restricted by the experimental design (specifically, by the sample size and the dose intervals) of the bioassay; this in turn limits the possible values of carcinogenic potency which can arise (Reith and Starr, 1989a,b). For example, Bernstein *et al.* (1985) showed that in a one-hit model analysis of an idealized two group design with a 10% background incidence, a test group of 50 restricted the possible values for potency (B) to lie within a factor of about 30 surrounding the inverse dose tested. When one considers that the range of possible doses across chemicals tested in the chronic bioassay is greater than seven orders of

magnitude, this restriction on B due to limited sample size forces it to be essentially equivalent to the inverse dose tested. Reith and Starr (1989a,b) have claimed that due to this restriction, Wilson *et al.* (1984) and Ziese *et al.* (1984) erroneously concluded that there was a relationship between LD_{50} and chronic carcinogenic potency. They showed that although the results of acute testing appeared to predict the potency of mutagenic, chemical carcinogens, the relationship was simply an artifact of the bioassay test method and should not be relied upon to predict a chemical's carcinogenic risk.

It would be desirable for the selection of different low-dose models to be based on statistical tests of fitness. However, as noted by Munro and Krewski (1981); since the various low-dose extrapolation models fit the data well in the observable range, it is not possible to select an appropriate model or range of risks using statistical criteria alone. This assertion was recently discussed by Sielken (1987a,b), later critiqued by Crump (1988), and responded to by Sielken (1988). Since only data gathered at relatively high doses are available and because such doses may produce biochemical and pharmacokinetic changes that will not occur at much lower doses, mathematical criteria alone will never take the place of a biologic basis for extrapolation. When estimating the carcinogenic risk to humans, a wide variety of biological data should be considered. These include data from acute, subacute, and chronic exposure tests in animals, metabolism in a variety of species, *in vitro* mutagenesis, route of exposure, mechanism of action, epidemiology, and pharmacokinetics (Sielken, 1985).

There is a growing sentiment that the maximum likelihood estimate may well be a superior method for expressing risk rather than discussing only the upper bound of the risk. As shown in Fig. 4, the procedure most commonly used to determine the upper and lower bounds of risk necessitates that the bounds encompass a large range. EPA currently uses the linearized multistage model as a fallback procedure for extrapolation of high-dose data to low exposures and it has been customary to present only the upper bound estimates. No provision exists in the EPA Guidelines for an expression of "more probable than not" estimates of risk in addition to, or instead of, the upper bound estimates. Specifically, the guidelines currently state (EPA, 1986e):

> It should be emphasized that the linearized multistage procedure leads to a plausible upper limit to risk that is consistent with some proposed mechanisms of carcinogenesis. Such an estimate, however, does not necessarily give a realistic prediction of the risk. The true value of the risk is unknown, and may be as low as zero. The range of risks, defined by the upper limit given by the chosen model and the lower limit which may be as low as zero, should be explicitly stated. An established procedure does not yet exist for making "most likely" or "best" estimates of risk within the range of uncertainty defined by the upper and lower limit estimates.

Even though established generic procedures have not been formalized for making "most likely" or "best estimates" of risk, it should be possible, for individual substances, to reach a consensus on a narrower range for the most probable risk than is currently practiced by drawing on statistical and/or biologic criteria, or the results of epidemiology data.

Biologic Factors

In short, although it is important to understand the mathematical basis of the various extrapolation models, the critical shortcoming of these models is their inability

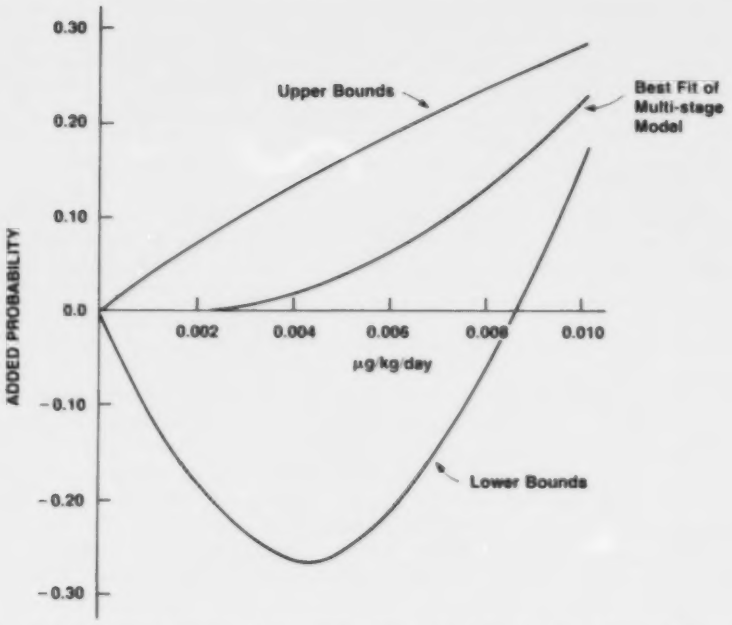

FIG. 4. An illustration of the range of plausible risks using the bounding technique inherent in the multistage model. This specific depiction is based on the application of the Three-Stage Multistage Model to the Responses observed in the CIIT Inhalation Study of Formaldehyde. Reprinted with permission from Robert L. Sielken, Jr. (1987c). The capabilities, sensitivity, pitfalls, and future of quantitative risk assessment. In *Environmental Health Risks: Assessment and Management* (R. S. McColl, Ed.). University of Waterloo Press, Waterloo, Ontario. Copyright 1987, by the Institute for Risk Research, University of Waterloo, Waterloo, Ontario.

to account for biological factors which may modify the response at very low levels. These include the numerous protective mechanisms within complex living animals (Bus and Gibson, 1985) and the pharmacokinetic changes which may occur only at high doses (Hoel and Andersen, 1984). Further, the typical use of extrapolation models by regulatory agencies does not account for the pharmacokinetic differences between the test species and humans (Ramsey and Andersen, 1984; Clewell and Andersen, 1985). Last, the current models used by regulatory agencies do not differentiate among the various eight or more different mechanisms of carcinogenesis (Butterworth, 1987). As noted by Ames (1987),

> the fact that high doses of a chemical cause tumors does not mean that small doses will. Most of the carcinogens we are worrying about in pollution, may, in fact, be harmless at low levels . . . Some chemicals damage DNA and some do not, and this makes an enormous difference in how we should deal with them at low doses.

Because of these shortcomings, a good deal of emphasis has been placed on developing biologically based models for disposition and the carcinogenic response so that

less emphasis will need to be attached to statistical approaches (Swenberg and Short, 1987).

In addition to the concern that modeling approaches may overestimate the risk over the continuum of doses, many toxicologists believe that the assumption of a lack of a threshold for all carcinogens is no longer defensible (Butterworth, 1987). Ames (1987) has claimed that there is no epidemiological evidence that exposure to very low doses of environmental chemicals pose a risk of cancer and that many chemicals listed as carcinogens act only through nongenotoxic mechanisms. Only a few years ago, it was hoped that fast and inexpensive bacterial tests could be used (instead of 2-year rodent studies) to identify likely human carcinogens. Perhaps recognition that there is no simple way to identify those chemicals which may pose a cancer hazard to humans at levels seen in our environment is one of the biggest changes in risk assessment that occurred in the 1980s. A recent study illustrates why simple approaches will not work. Seventy-three chemicals were evaluated in a major National Toxicology Program/National Cancer Institute (NTP/NCI) study to examine the correlation of the activity in short-term tests with activity in cancer bioassays (Tenant *et al.*, 1987). The NTP/NCI study and other work showed that if the weight of evidence indicated that a chemical was a mutagen then in approximately 90% of the cases that chemical did turn out to be carcinogenic in some animal model (McCann *et al.*, 1975; McCann and Ames, 1976). This very high degree of positive productivity is strong evidence that mutational events are a key step in carcinogenesis.

However, tests for mutagenic potential are only valid if they are based on actual events that occur in the process of carcinogenesis. Whether one is dealing with results from a mutagenic assay or short-term tests for genotoxicity, the right answer for the wrong reason is of little value (Butterworth, 1987). For example, in the NTP/NCI study the converse to the mutagen/carcinogen relationship was not true. A chemical that was not mutagenic often did turn out to be a carcinogen, simply because the chemical appeared to be working through a nongenotoxic mechanism. Interestingly, not a single chemical in the NTP/NCI study that required over 500 mg/kg/day to produce cancer was an Ames test mutagen (Tenant *et al.*, 1987).

In recent years, a large segment of the scientific community has concluded that for nongenotoxic carcinogens, a level of exposure should exist below which no appreciable risk would be present (Weisburger and Williams, 1986). Examples often cited include nitrilotriacetic acid (NTA), phenobarbital, unleaded gasoline, the giotrogens, diethylhexylphthalate (DEHP), and dioxin. Mathematical approaches to predict the theoretical tumor incidence at doses far below those where tumors were actually observed have been proposed for nongenotoxicants. These fall into two categories, those that are laden with historical experience and those based in relatively complex mathematical/biological analysis.

Critics of models point at the lack of agreement among them. For example, when calculating the maximum likelihood estimates of cancer risk for exposure to 0.1 ppm formaldehyde, the values from the probit and multistage models differed by 19 orders of magnitude (Starr and Buck, 1984). These critics claim that there is ample evidence, for the nongenotoxicants, to use uncertainty factors (Butterworth, 1987). They assert that if induced toxicity and hyperplasia are the driving force for the production of tumors for some of the high-dose nongenotoxic carcinogens, then no increased risk of cancer would be anticipated at doses below those where these effects do not occur. Accordingly, it has been proposed that a NOEL with a safety factor would be a ra-

tional risk assessment model for experimental carcinogens that exhibit all of the following properties: (a) the chemical is nongenotoxic; (b) over 500 mg/kg/day was required to produce tumors; (c) tumors were seen only at the end of the study; (d) pathological lesions were observed in the target organ before tumors were produced; and (e) tumors appeared only in that single target organ (Butterworth, 1987). The pros and cons of modeling have been hotly debated in recent years and it is likely that the differences of opinion will not be resolved until our understanding of cancer mechanisms and how to model them are significantly improved (Perera, 1984, 1988; California DHS, 1986; Finkel, 1989; Paustenbach, 1989b; Wilson, 1989; Anderson, 1989).

Attempts to Consider Weight of Evidence (Dioxin)

By 1986, a significant fraction of the scientific and regulatory communities began to move away from a strict reliance on the results of statistical models for estimating cancer risks. Perhaps the best example of the change is the EPA proposed risk specific dose for dioxin (EPA, 1988b). In 1978, the EPA was faced with data which indicated that TCDD was a potent carcinogen in at least two bioassays and that it had high acute toxicity. In addition, at least two reports indicated that persons exposed to pesticides in Europe which might have contained TCDD appeared to have an increased incidence of soft-tissue sarcoma. One researcher had reported that TCDD had mutagenic potential. In 1982, the EPA used its customary conservative assumptions in the interpretation of the bioassay data and estimated that a dose of 6 fg/kg/day could be associated with a risk of 1 in 1,000,000 (10^{-6}). Indeed, such an estimate implied that the presence of measurable levels of TCDD in our food, water, air, or consumer products might pose a significant health risk.

By the end of 1987, more information on dioxin had become available and the EPA decided to reevaluate whether the 6 fg/kg/day figure was still reasonable. Much of the old data were evaluated. By 1989, the 1982 and 1984 epidemiology studies had been shown to be less than convincing (EPA, 1985; Bond *et al.*, 1987, 1989; Cook *et al.*, 1986). Occupational epidemiology studies had not shown an increased incidence of STS, even though exposures were often high enough to cause chloracne in a significant segment of the exposed population (Tschirley, 1986; Bond *et al.*, 1987). Alternative analyses of the dose–response data, when corrected for early animal death and saturation at the highest dose, indicated that a 10^{-6} risk could be associated with doses as high as 10,000 fg/kg/day (Sielken, 1987a). The two positive mutagenicity tests which suggested that TCDD was mutagenic were found to be seriously deficient (Shu *et al.*, 1987). Mutagenicity and cytotoxicity data from at least 10 other researchers showed the original results to be invalid, and based on the weight of evidence, it became generally accepted that dioxin was not genotoxic (EPA, 1988a).

Over the past 4 years, numerous European countries, Canada, and the U.S. Food and Drug Administration evaluated these data and decided that, in light of its lack of genotoxicity, TCDD probably had a threshold dose below which no additional cancer risk should be present (Paustenbach *et al.*, 1986; Shu *et al.*, 1987). Faced with these data, in December 1987, the EPA announced that they were considering raising the dose estimate for a risk of 1 in 1,000,000 from 6 to 100 fg/kg/day (Shabecoff, 1988). Although this was still markedly less than the 10,000 fg/kg/day value used in Canada

and some other countries, it represented an important turning point in the regulatory treatment of complex data sets for carcinogenic substances. EPA believed it was necessary and appropriate to alter its approach to risk assessment since the "weight of data" suggested that standard dose–response analyses did not properly reflect all the available biological and epidemiologic data. Interestingly, after a good deal of public and scientific debate, it appears that the EPA's Science Advisory Board will suggest to EPA that the data remain insufficient on dioxin to depart from the traditional approach to estimating the low dose response (Silbergeld, 1988a; Perera, 1988; Moore, 1988; Wilson, 1988; Finkel, 1988).

Pharmacokinetics

One of the most exciting and important advances in risk assessment has been the application of pharmacokinetics to interpret rodent and human data. Pharmacokinetic modeling can be divided into two subcategories: physiological or compartmental. The compartmental model and approach attempts to fit the blood concentration vs time profile of the parent or the metabolite to a nonlinear exponential model which is a function of the administered dose of the parent chemical. The model can be rationalized to correspond to different "compartments" within the body. Physiological models, unlike compartmental models, have the capability to accurately simulate drug/chemical behavior in biological systems. The purpose of PB-PK models is to predict the human response at environmental levels based on animal data at much higher, more easily characterized, exposures (Clewell and Andersen, 1985). Physiologically based pharmacokinetic (PB-PK) models, more recently called biologically based disposition models, represent perhaps one of the most important breakthroughs in risk assessment since they allow for accurate scaling up of rodent data to estimate human risk (Paustenbach, 1989).

Physiologically based models differ from compartmental models in that they are based on the actual physiology and biochemical behavior in the test species, as well as the physical and chemical properties of the test agent. Instead of compartments defined by the experimental data, actual organ and tissue groups are evaluated. After a conceptual model of the chemical's behavior is developed, mass-balance differential equations are written to describe the behavior of the chemical in each of the biologically relevant compartments. These models can be adapted to accommodate such biological events as nonlinear tissue binding, Michaelis–Menten elimination, parallel organ specific elimination, enzyme induction and inhibition, biliary recycling, diffusional resistance across cell membranes, receptor number and affinity, etc. (Clewell and Andersen, 1985; Menzel, 1987; Reitz *et al.*, 1988).

Physicochemical and blood flows are utilized throughout the PB-PK model. Physicochemical and biochemical constants of the compound allow the creation of a model which has greater predictive power than classic compartmental models. Because actual metabolic parameters are used, dose extrapolations can be carried out over ranges in which saturation of metabolism occurs. Most importantly, because known physiological parameters are used, a different species can be modeled by replacing the appropriate constants. Different routes of administration can be accounted for by adding equations which describe the nature of the new function. Between 1984 and 1989, PB-PK models were developed for a number of industrial

chemicals, including kepone, methylene chloride, styrene, perchloroethylene, polychlorinated dibenzofurans, carbon tetrachloride, dioxane, methyl chloroform, methylene chloride, and ethylene dichloride and dioxin (D'Souza and Boxenbaum, 1987; Paustenbach *et al.*, 1988). Two conceptual models are presented in Fig. 5.

The power of biologically based disposition models was demonstrated by Andersen *et al.* (1987) in their analysis of the cancer risk posed by low levels of exposure to methylene chloride. They showed that, due to the behavior observed subsequent to high-dose exposure, one could not predict the low-dose response in humans without correcting for a number of metabolic, physiological, and pharmacokinetic factors. After applying the appropriate corrections and developing a model which could accurately predict the chemical's behavior in rodents and humans, these researchers determined that the highest plausible dose associated with a risk of 1 in 1,000,000 was overestimated by about 144-fold when a nonpharmacokinetic approach was used.

Not only can PB-PK models describe complex phenomenon needed to quantitatively understand health risk, but they can also help explain the difference in biologic response between animals and humans. For example, Leung and co-workers (1988a, 1989a,b) recently developed a PB-PK model for dioxin wherein they showed how differences in the number and affinity of receptors in the liver could explain the differences between two species of mice. Although they did not speculate how this might affect the low-dose extrapolation, they noted that a PB-PK model for TCDD should be useful in risk assessments for humans. A validated model that accounts for the difference in dioxin concentration in the liver among species might well explain why rodents appear more sensitive than humans to dioxin since rodents have liver concentrations 10- to 100-fold higher than humans exposed to similar doses. The same model might also help explain TCDD's long half-life in humans.

Biologically Based Cancer Models

Although the development and use of biologically based disposition (PB-PK) models represents a significant improvement in our approach to understanding the likely human response due to improved methods for scale up, perhaps an even more important contribution to cancer risk assessment is the development of biologically based cancer models. It is quite likely that in the 1990s these models will displace statistical models which only evaluate the quantal data from bioassays. The first, and perhaps most promising, of these models was developed by Moolgavkar and Knudson (1981). Despite its simplicity and the diversity of the disease processes categorized under the heading of cancer, the model is very compelling. It is a form of the two-stage model initially described by Armitage and Doll (1954). In this model, cancer is explained as the end result of two mutagenic events that correspond to mutations at a critical gene locus. In the human, these mutations are duplicated within the genetic material of the cell. As discussed by Andersen (1988), the first event produces an intermediate cell type that may have different growth characteristics than the normal cell but one that is not aggressively malignant. A second irreversible event is necessary to complete the cell transformation process, alter the second locus of the critical gene, and obtain the cancer cell which grows into a tumor by clonal expansion (Fig. 6).

Using this model, one can explain how genotoxicants alter mutation rates, how cytotoxicants alter cell death and birth rates of the normal and intermediate cells,

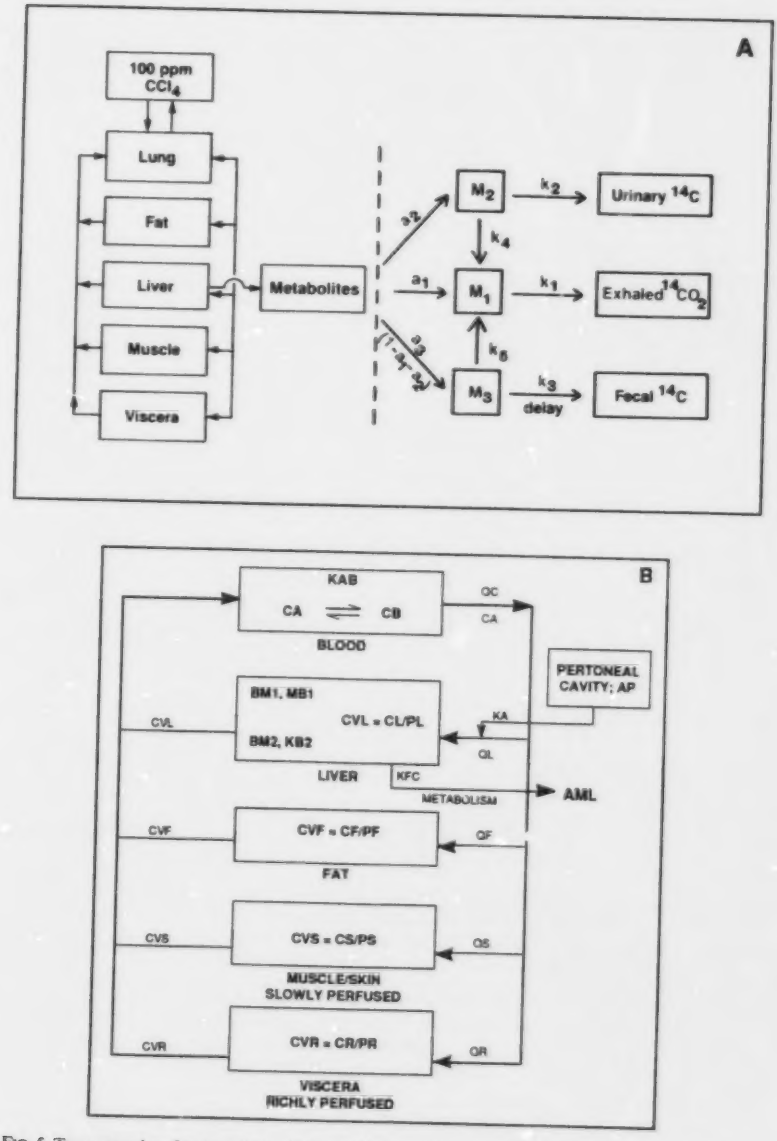

FIG. 5. Two examples of a physiologically based pharmacokinetic model. (A) The description of a model for carbon tetrachloride (from Paustenbach *et al.*, 1988) and (B) for 2,3,7,8 TCDD (from Leung *et al.*, 1988a). More recently these have been called biologically based disposition models.

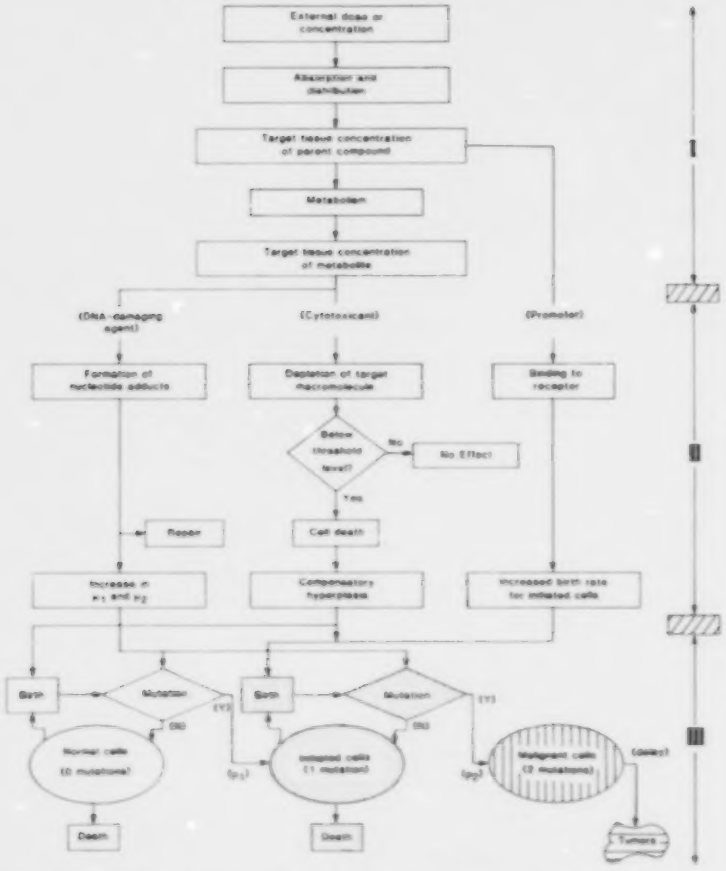

FIG. 6. Schematic diagram of carcinogenic processes accounted for within the pharmacodynamic cancer models (PCM). Part I is a physiologically based description of the processes controlling carcinogen pharmacokinetics. In this segment the external dose, such as mg/kg/day ingested, is converted to a realistic target tissue concentration of either the parent compound or the relevant metabolite(s). In part II, representative biochemical mechanisms are described for three distinct classes of carcinogens: DNA-damaging agents, promoters, and cytotoxicants. Part III consists of a two-stage cancer model where cells are normal, intermediate, or malignant (0, 1, and 2 mutations, respectively). The linkages between parts II and III specify how the different kinds of carcinogens affect the cell growth and mutation parameters of the cancer model (from Conolly *et al.*, 1988).

and how promoters convey growth advantages on the intermediate cell populations. This approach, which has already been applied by Thorslund *et al.* (1987) and Conolly *et al.* (1988) may well be the foundation upon which future cancer risk estimates will be based. Most importantly, the use of biologically based disposition models,

coupled with the biologically based cancer models, should produce more realistic estimates of risks at low doses. It is plausible that such approaches could be used in regulatory decision making as early as 1991 if sufficient attention is directed to these efforts by scientists within government, academia, and industry.

RISK CHARACTERIZATION

The risk characterization step is a discussion which sums up all the information which has been gathered and presents it in a useful and understandable manner. To do this, the risk characterization should contain not only a risk estimate for a given exposure scenario but also a summary of the relevant biological information, the assumptions used and their limitations, and a discussion of uncertainties in the risk assessment, both qualitative and quantitative (Preuss and Ehrlich, 1987).

Although we know how to do a better job in the hazard identification, dose–response assessment, and exposure assessment portions of risk assessment than we did 10 years ago, we have only begun to properly characterize the risks and present them in an effective manner to decision makers. If there is any doubt about this claim, one need only read newspaper accounts of the scientific positions of regulatory agencies attempting to characterize the severity of some hazards:

> Excess deaths from lung cancer due to workplace arsenic are down 98%, says the Occupational Safety and Health Administration, based on risk assessment studies. The arsenic standard of OSHA requires engineering controls and other measures to reduce worker exposure from 500 to 10 $\mu g/m^3$. Three risk assessments performed under federal court order on the standard's efficacy indicate that excess deaths (relative to the general population) dropped 8–10 per 1000 workers from the 375 to 465 per 1000 that would have occurred under the previous 500 $\mu g/m^3$ standard. (Anonymous, 1982)

Among the numerous shortcomings of the above news report is that the reader will probably infer that, under the old OSHA standard, as many as 46.5% of the worker population was likely to die prematurely from cancer due exclusively to occupational exposure to arsenic. In actuality, there has been a good deal of discussion about whether any increased cancer risk had been observed in epidemiology studies of workers who had been exposed to levels in the vicinity of 500 $\mu g/m3$. In short, the proposed regulation may well have had no appreciable effect on the cancer rates in these workers since it is possible that their exposures at the prior PEL exposed them to no increased risk. In addition, in an attempt to demonstrate the potential benefits of regulation, much more certainty was attached to the possible results of the action than was actually present in the low-dose extrapolation process. In short, it seems that we have not developed an effective way to communicate risk issues in a thorough, easily understood, and objective manner (Covello and Menkes, 1986).

When characterizing the risks associated with exposure to a carcinogen, a developmental toxicant, a mutagen, or a mixture of different chemicals, emphasis needs to be placed on the characteristics and shortcomings of the dose–response extrapolation and exposure assessment. Since issuance of the OSTP and EPA risk assessment guidelines of 1985 and 1986, greater importance has been placed on adding a discussion to the risk characterization which addresses the weight of evidence for selecting certain parameters or assumptions in the assessment. The weight of evidence thought process has grown out of a concern that often only one piece of "negative data" seemed to

dominate a risk assessment even though a more scientifically defensible "positive data" set may have been available. Several papers that illustrate the importance of the weight of evidence approach to selecting important parameters in a risk assessment have been published (Maxim and Harrington, 1984; Turnbull and Rodricks, 1985; Paustenbach *et al.*, 1986; Shu *et al.*, 1987; Paynter *et al.*, 1988). It can be anticipated that risk characterizations written in the 1990s will contain lengthy discussions of this topic.

Recently, Ames and colleagues (1987) proposed that one way to characterize the human health hazard posed by low level exposure to industrial carcinogens was to compare their risk with those risks posed by naturally occurring carcinogens in our diet. They suggested that a comparison of the likely dose to which people are exposed versus the median dose in the test bioassay could be used to rank the hazard, an index they termed "HERP." The purpose of the paper was to stimulate discussion about how to best characterize the risks posed by xenobiotics. For example, their analysis suggested that low levels of synthetic pollutants in drinking water and foods posed a negligible hazard compared to the background of natural carcinogens. They indicated that if the public were to be presented with this type of information, we might spend our resources differently.

The other key portion of the risk characterization is a complete discussion and analysis of the uncertainties. The portions of the assessment which benefit most from uncertainties and sensitivity analysis are the dose–response and exposure segments. Very interesting analyses of the low-dose extrapolation models have been conducted using simulations. These have illustrated some of the shortcomings that can occur when too much emphasis is placed on point estimates of risk (Sielken, 1989). In addition, specific mathematical techniques have been developed for assessing both uncertainty and parameter sensitivity when attempting to estimate dose, especially for multipathway exposures (inhalation and dermal uptake of vapors and particles, ingestion of contaminants via the food chain and incidental soil ingestion, etc.). For example, the probability distribution of the results of the exposure assessment can be estimated (Eschenroeder and Faeder, 1988). Such an approach offers the hope that, rather than having to state that "it is plausible that someone might absorb as much as 100 fg/kg/day of a given chemical which is released by automobiles and can be taken up both by direct contact and the food chain," we might be able to say that "the data indicate that perhaps 0.5% of the population might absorb as much as 100 fg/kg/day, 76% might absorb 5 fg/kg/day and 23.5% are likely to absorb less than 1 fg/kg/day of the chemical."

Perhaps the most important aspect of risk characterization is the description of the severity of the risk posed by exposure to a chemical vs risks which have traditionally been of concern. Recent papers have addressed this issue in two different fashions: (1) what level of environmental risks have warranted regulation and (2) how high are the risks of exposure to environmental contaminants compared to risks which we generally consider acceptable (Travis and Hattemer-Frey, 1988a). Travis *et al.* (1987) evaluated nearly 200 regulations involving chemicals in our diet, water, and air. They found that regulation was usually driven by three factors: the individual risk level, the risk burden to the exposed population, and the number of persons potentially exposed to significant levels. They found that regulation most frequently occurs when the individual risks are greater than 10^{-4} or when the risk burden is greater than 10 when the population exceeds 100,000 persons (Fig. 7). In contrast, Rodricks *et al.*

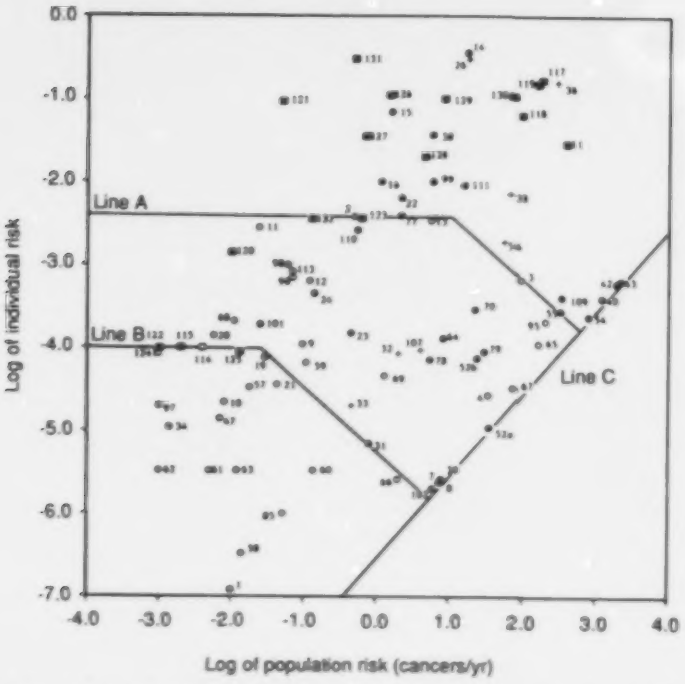

FIG. 7. A compilation of the individual risk levels inherent in various regulatory decisions as a function of the number of exposed persons. Line A defines the de manifestis level; above this line, federal agencies always acted to reduce risk. For exposures resulting in a small-population risk, the de manifestis level is approximately 4×10^{-3}. As population risk approaches 250 cancer deaths (which could only occur in a population the size of the entire United States) the de manifestis level drops to about 3×10^{-4}. Line B shows the de minimis level. Below this line, no action has ever been taken to reduce risk. Line B indicates that for small-population effects, regulatory action was never taken for individual risk levels below 10^{-4}. For effects resulting from exposures to the entire U.S. population, the level of acceptable risk drops to 10^{-6}. Line C is the area beyond which no data can fall. Reprinted with permission from C. C. Travis, S. A. Richter, E. A. C. Crouch, R. Wilson, and E. D. Klema (1987). Cancer risk management. *Environ. Sci Technol.* **21**, 415–420. Copyright 1987 American Chemical Society.

(1987) showed that occupational risks for individuals exposed to current workplace air standards are usually in the region of 10^{-3} to 10^{-4}.

Another area that has received increased attention is that of the risk/benefit and cost/benefit ratios. As shown in Fig. 8, the cost of remediation almost always decreases logarithmically with decreasing clean-up levels. It can be expected that during the 1990s, as was true during the Reagan Administration, greater emphasis will be placed on the careful allotment of America's limited financial resources. However, the care that will be exercised in deciding which problems to tackle should not be misunderstood to mean that concern for the environment has lessened. Indeed, Americans rank cleaning the environment near the top of their list of priorities (Easterbrook, 1989).

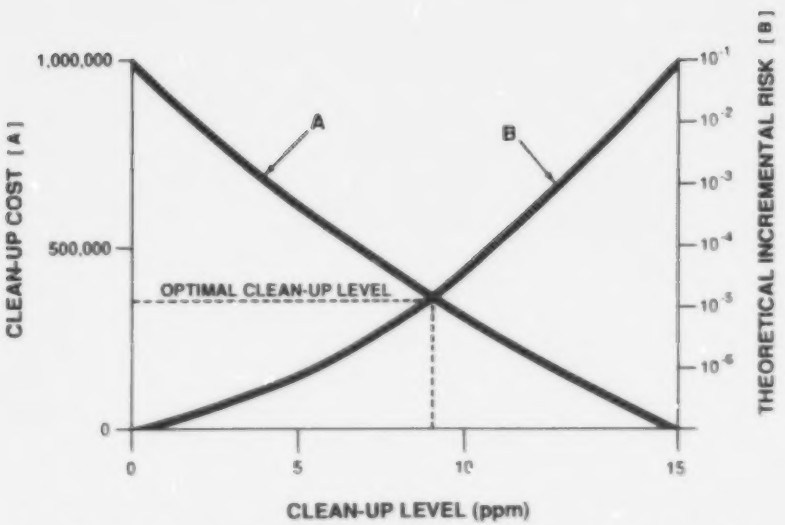

FIG. 8. This plot illustrates how the optimal level of cleanup of soil at a site can be selected by considering the degree of risk reduction associated with the costs involved in meeting specific clean-up criteria (based on Anderson, 1987b).

CONCLUSIONS

The future of risk assessment looks promising. Our more enlightened approaches to interpreting the significance of animal bioassay data should provide much more defensible hazard identifications. Biologically based disposition and cancer models should provide better estimates of the actual human cancer risk, thus improving the dose–response segment. Reliance on worst case exposure scenarios will no longer be necessary in light of better information on specific exposure parameters and the application of statistical approaches for handling Gaussian and lognormal distributions. Such approaches will give us greater confidence that our exposure assessments yield reasonable estimates of the actual degree of human exposure. Last, our awareness of the numerous uncertainties in the process, as well as our knowledge of how to best characterize them, will almost certainly be better explained in future assessments. Ultimately, these improvements should make the job of the risk assessor and risk manager significantly easier since the degree of uncertainty in the procedure will have been markedly reduced. These more accurate assessments should allow us to place our monies and efforts on those problems which truly deserve our attention. Already, the implementation of some of these concepts has shown that we almost certainly overestimated the severity of many human health hazards. As a result, scientists will be focusing more of their efforts on the evaluation of environmental hazards.

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PROCEDURES FOR ESTABLISHING PRIORITIES AMONG TOXIC AIRBORNE POLLUTANTS

by

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Abstract. A review was undertaken of the scientific literature pertaining to ranking procedures for environmental contaminants, and on national, regional and local programs in North America for assessing and controlling airborne toxic chemicals. One objective of this review was to identify and evaluate strategies for establishing priorities within programs intended to assess and regulate atmospheric contaminants. The characteristics of programs addressing near-source and long-range impacts of toxic airborne contaminants are differentiated and discussed. Selected existing programs are compared and contrasted for the benefit of those agencies interested in developing airborne toxic chemicals assessment and/or control programs. Hazard assessment and risk analysis procedures are useful tools for setting chemical priorities within regulatory programs, but their application to ambient environmental contaminants - airborne toxics in particular - is difficult, because of the complexity of exposure assessment. Some of the issues and strategies are discussed.

Introduction. A literature review[1] conducted in 1985 provided the basis for subsequent development in the Federal-Provincial Advisory Committee on Air Quality (FPACAQ) of an approach to choosing a list of priority airborne toxic substances for Canada. In addition, the Canadian Environmental Protection Act (CEPA) Priority Substances List (PSL)[2] lists 44 chemicals or families of chemicals in three priority groups. Of these substances, 35 are potential air pollutants, that is, have significant atmospheric pathways into the environment. FPACAQ has proposed another 21 chemicals for inclusion with the CEPA/PSL air pollutants in a hazardous air pollutants list.

Both the CEPA/PSL and FPACAQ lists are candidates for assessment - the preliminary step of regulation. Some of these 56 chemicals will probably be regulated in the future. Over the next several years, the assessment of these chemicals will involve both toxicological and exposure assessments - the two components of risk assessment.

The exposure assessment component is discussed in this paper.

Approaches to Priority Setting. The first task is to establish objectives for the priority-setting exercise. Such constraints are necessary to assure that the outcome of the activity will be useful. Objectives will normally be determined by legislative and program definitions or requirements. Priority-setting is usually necessary because of resource limitations, and managers of program elements need to know where to start. Priorities may differ for programs or elements focused on toxicological research, for example, compared with exposure assessment or regulation development. It is presumed at this stage in the development of hazardous air pollutant

control strategies that the primary purpose of priority-setting is to assign resources to exposure assessment by such means as monitoring or emission/source inventories combined with exposure modelling. This presumption is based on the availability of toxicological and physical/chemical property data for a large number of environmental contaminants and the absence of exposure data which would allow an assessment of the need to regulate a particular chemical or source. The goal of these activities is, of course, to identify candidate chemicals or sources for the costly process of regulation development.

If the objective of priority-setting is to identify chemicals for exposure assessment, what are the possible approaches?

The following ideas were presented in a report to FPACAQ[3]. The approaches may be categorized as

- Synthesis of expert opinion (the "wise person" approach)
- Compilation of existing priority lists from other agencies
- Quantitative scoring / ranking systems.

The CEPA/PSL is a product of the "wise person" approach, making use of expert judgement of the Ministers' Priority Substances Advisory Panel (chaired by Professor Ross Hume Hall) and of professionals within Environment Canada and Health and Welfare Canada. Ontario's Hazardous Contaminants Program and many U.S. states have used the second of these approaches. Quantitative scoring and ranking systems have been used by Ontario's MISA and Clean Air Programs and by the U.S. Environmental Protection Agency and several states.

Expert judgement must play a role in the priority-setting process, because the complex nature of the transport, transformation, fate and effects of the mixture of contaminants which is emitted and discharged into the environment cannot be addressed yet by simple numerical ranking systems. There may be a role here for expert systems (artificial intelligence, AI)[4], but insufficient information exists currently to drive such systems to set national priorities. AI systems have been developed for site- or source-specific assessment applications, such as waste management facilities, site decommissioning and airport development impacts[4]. In one exercise in Ontario[5], however, the results of a numerical scoring process agreed quite well with a ranking by independent expert judgement of a selected group of chemicals.

It is important that priority lists be used in context. That is, the limitations of data availability, data quality, and information bias need to be recognized. The scientific and policy limitations of any priority list also suggest that priorities must be flexible enough to adapt to new information and interpretation - not cast in concrete. These issues are addressed in a paper by Hushon and Kornreich[6], to which readers are referred.

Candidate Chemical Lists. The first step in developing a priority list is to compile a candidate list of chemicals (or sources). This is not as simple as it may appear. Lists tend to evolve from existing lists without regard for the quality of information, which may bias some entries. If appropriate list selection criteria are used and care is taken to look for errors and omissions, compilation of a composite list can be done with

reasonable confidence. Since air is not isolated from other environmental media, and environmental contaminants move freely from one medium to another, priority lists should be, ideally, comprehensive and multi-media in scope. Few regulatory instruments, particularly in Canada, are multi-media or ecosystem-oriented; therefore, regulatory programs tend to treat contaminants as they affect a single medium. Air pollutants may be defined as "contaminants which impact receptors primarily through the atmosphere," but this definition must be recognized as limited. Priority air pollutants, then, should be those contaminants from a multi-media list whose pathways from source to receptor significantly involve the atmosphere.

If a multi-media list is not developed, an air pollution control agency needs to decide whether a priority list is intended to address direct effects only (e.g., by inhalation), or whether indirect effects will also be addressed (e.g., by aerial transport / deposition / aquatic or terrestrial uptake). The distinction between direct and indirect effects may be equated to local and long-range scales. Many regulatory instruments address only local source impacts. The long-range transport of toxic air pollutants, however, is an issue which is related to other LRTAP issues, such as, acidic deposition and oxidants. Hazardous air pollutants have been shown to travel long distances (e.g., polycyclic aromatic hydrocarbons from central Europe to Scandinavia) and to undergo potentially significant chemical transformations during transport. These issues are addressed by Mellon *et al.*[7]

Ranking a Candidate List. Once a list of candidate chemicals has been developed, it may need to be further ranked in order to permit staged allocation of resources. For example, the CEPA/PSL has been grouped into three levels of priority for completion of assessments on a schedule of three, four and five years. Chemicals within a group on the PSL are not ranked. It may be desirable to rank chemicals numerically for the purposes of some programs. Numerical scoring systems can achieve this objective, but they must be used with caution, since they produce an apparently quantitative ordering which may take on a mistaken aura of physical reality. Ontario's Vector Scoring System or the U.S. E.P.A.'s MHAPPS (Modified Hazardous Air Pollutant Priorization System) have proved to be useful screening tools for lengthy candidate lists, but it must be recognized that their numerical scores must be evaluated to make sure that the results make sense.

U.S. E.P.A. has departed from regulating individual chemicals as hazardous air pollutants and will concentrate on sources or source categories associated with hazardous air pollutants. This strategy is illustrated by the U.S. Clean Air Act Amendments (e.g., Bill H.R. 3030, "The Clean Air Act Amendments of 1989"). In this preliminary proposal, more than 180 substances (or classes) are listed, and the intent is to regulate categories or subcategories of designated major sources or area sources of substances on the Hazardous Air Pollutant List. This approach may be more efficient than chemical-by-chemical regulation. A priority list of sources could be generated by identifying the principal sources of the highest ranking individual chemicals.

Conclusion. At present, the categorical ranking of those CEPA/PSL substances which are primarily air pollutants serves as a guide to priorities for air pollution control agencies in Canada, for exposure or risk assessment purposes. Amplification of this list may be desirable because of additional significant hazardous air pollutants which are associated with the sources of the listed chemicals and because of the specific requirements of provincial and municipal agencies, whose approaches to air pollution may differ from that specified in CEPA. Provinces may wish to determine whether the PSL chemicals are associated with sources under their jurisdiction.

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EMERGENCY RESPONSE RISK ASSESSMENT AND ENVIRONMENTAL CONTAMINATION CLEANUP CRITERIA

Dennis L. Greaney and William B. Hope, Jr., Sc.D.

The cleanup of hazardous waste sites is a relatively new technology with the vast majority of site remediations occurring since the 1980 adoption of CERCLA (Superfund) by the USEPA. The cleanups of hazardous waste sites can be broadly categorized as either Remedial Removal or Emergency Removal Actions.

Remedial projects are typified by a lengthy period of study (Remedial Investigation/Feasibility Study or RI/FS), sometimes with study periods of between 5 and 10 years. Equally important to the length of time allowed in studying a site is the fact that the RI/FS is controlled by a single government agency and follows a well defined documentation procedure. Included in the procedure is a risk assessment, carried out by ATSDR (Agency for Toxic Substance and Disease Registry) that defines, among other parameters, a site specific soil cleanup criteria.

Cleanup criteria are developed on a site specific basis. These criteria represent the cleanup objectives warranted by the level of contamination, associated health risks, and environmental fate of the specific contaminants. This will assure the site as free of hazards after completion of cleanup activities. Stated another way these cleanup criteria represent the site and chemical specific level of contamination calculated to represent an acceptable risk if left in the environment. An example of the accepted level of soil cleanup of 2,3,7,8-

Tetrachlorodibenzo-p-dioxin (TCDD) in residential areas is 1 ppb. It follows that residual levels below 1 ppb represents an acceptable risk in residential areas. The methodologies used in long term risk assessments will not be addressed in this paper. Numerous technical documents exist outlining the currently used procedures.

Emergency response removals are different in several respects from remedial projects. Typically such removals are defined by little or no investigation phase and require immediate remediation. Equally important to the inability to pre-plan is the fact that environmental emergencies predispose themselves to immediate often chaotic activity by local, state and/or federal agencies. The inability to pre-plan, combined with a need for interagency and multi-agency interaction and the lack of established soil cleanup criteria, often leads to the establishment of erroneous or improper cleanup criteria.

TYPE I AND TYPE II CLEANUP CRITERIA ERRORS

Cleanup criteria errors occur in two forms. Borrowing from statistical hypothesis testing, a Type I Cleanup Criteria Error can be defined as the establishment of cleanup criteria that do not meet an acceptable risk in the environment. The results of such an error would be the acceptance of a cleaned remediated site as being within an acceptable level of risk when it actually is not acceptable. A Type II Cleanup Criteria Error can be defined as the establishment of cleanup criteria that requires site cleanup beyond the level of acceptable risk. The results of this error could be the non-acceptance of an acceptable risk site resulting in continued remediation efforts.

Common sense tells us that the Type II Error is more acceptable from a public health standpoint, than a Type I Error. Obviously it is better to overprotect human and environmental health than to jeopardize it. However, the principle of overprotection is most often abused and has serious drawbacks. (See Figure 1)

In order to realize how such mistakes are made and minimize future mistakes, it is important to introduce both the availability and assumptions of the commonly used approaches as well as some less familiar approaches.

Approach I Non-Detect/Backround

Approach II RCRA E.P. Toxicity

Approach III California Assessment Manual

Approach IV Multimedia Environmental Goals

Approach V Dioxin Equivalencies for Suspected Carcinogens EPA Methods

(A) Dioxin Equivalencies for Suspected Carcinogens

Approach VI Acceptable Chronic and Acceptable Subchronic Intake

CLEANUP CRITERIA

	TYPE I ERROR	TYPE II ERROR
Results	■ Post cleanup contamination remaining on-site thought to pose acceptable risk but poses unacceptable risk.	■ Site cleanup continues beyond acceptable risk.
Most Frequent Causes	■ All risks not accounted for or known. ■ "Creative Sampling" actually not criteria problem but a verification sampling problem.	■ Unfamiliarity with available toxicological/ environmental resources. ■ Lack of time to carry out full risk assessment. ■ Lack of Data. ■ Politics.
Problems	■ Chronic health effects may develop from long term exposure. ■ Increased future liability.	■ Increased cost of cleanup. ■ Weakens court case for later cost recovery. ■ Promotes non-reporting of spills in industry.
Solutions	■ The chance of a Type I Error occurring will decrease with increased toxicological and environmental fate data. ■ An increased recognition of past mistakes will occur with increased toxicological and environmental fate data.	■ Education of health agencies of available resources. ■ Development of larger data bases. ■ Removal of detrimental political interactions.

APPROACH 1
NON-DETECT/BACKGROUND CRITERIA

DEFINITION

By definition this approach requires the cleanup of contaminants to levels either non-detectable using current analytical techniques (commonly used for organic contamination) or to levels found naturally in soils native to the spill location (i.e., commonly used for metals and radiation).

ADVANTAGES

- No data required, fast decision.
- Acceptable to public.
- Superficially logical, easy decision to make.

DISADVANTAGES

- No toxicological or environmental fate considerations used.
- Leading cause of Type II Errors.
- Drastic increase in remediation costs.
- Legally very difficult to defend.

ASSUMPTIONS

- Contaminant has zero environmental threshold.

SECTION 6
RES OFFICE LOCATIONS

LIMIT

- Most applicable for metals/Macroelements.

USES

- Used widely by citizen groups, Politicians, Environmental Activists, and Public Health Officials lacking in detailed knowledge of environmental cleanup requirements.
- Applicable in highly sensitive areas with highly toxic, stable contaminants.

APPROACH II
RCRA CRITERIA
(EP TOXICITY)

DEFINITION	The RCRA E.P. Toxicity criteria designates wastes as hazardous based on the leachability (Extraction Procedure) of toxic constituents. The levels of contamination in the extracted liquid from a sample are compared to National Drinking Water Standard. If a sample yields liquids in excess of Drinking Water Standards the material is defined as hazardous.
ADVANTAGES	- Provides a numerical value eliminating the need for judgmental decisions. - Fast judgement possible.
DISADVANTAGES	- Does not consider soil consumption or inhalation of dust born contamination. - Legally binding. - Environmental issues not addressed (human health only).
ASSUMPTIONS	- Based on soil leachate. - Toxicity based on Drinking Water Standards and 100 times attenuated factors.
LIMITS	- Very limited number of chemicals addressed.
USES	- When a material is listed, the RCRA criteria are widely used. - USEPA currently updating and reviewing various aspects of criteria.

APPROACH III
CALIFORNIA GUIDELINES
CAM (CALIFORNIA ASSESSMENT MANUAL)

DEFINITION

The CAM Approach was defined by the California Department of Health Services to identify hazardous and extremely hazardous wastes. The approach incorporates the EP Toxicity data as well as defines.

ADVANTAGES

- Flexible guidelines incorporating several facets/options.
- Incorporates RCRA requirements and expands list.
- Incorporates both Environmental and human health issues.
- Establishes guidelines for interpretation of toxicity data (haz. = less than 5000 mg/kg acute oral LD5O, less than 4300 mg/kg acute dermal LD5O, 8 hrs. inhalation LC5O less than 10,000 ppm, Acute 96h LC5O less than 500 mg/L - Aquatic.
- Legally binding sometimes (in California).
- Assumes environmental threshold exists.

DISADVANTAGES

- Limited chemical addressed.
- Toxicity evaluation guidelines requires time in recording toxicities.

ASSUMPTIONS

- Guidelines, not standards.

LIMIT

- Approximately 38 compounds covered.
- Toxicological guidelines limited by toxicological data.

USES

- Used to cleanup sites and release them from "hazardous waste property" status in California.

APPROACH IV
MULTIMEDIA ENVIRONMENTAL GOALS

DEFINITION

The MEG criteria consist of calculated values based on toxicological information, government guidelines, and environmental fate. MEG's are further broken down into DMEGs (Discharge Multimedia Environmental Goals), and AMEGs (Ambient Multimedia Environmental Goals). The AMEGs represent levels that pose no long term effects on human health and the environment.

ADVANTAGES

- Systematic approach.
- Based on extrapolation of toxicity data in multiple environmental media.
- Separate limits for air, water and soil.
- Both environmental effects and human health considered.
- Generally accepted as reasonable in defining "rough" cleanup criteria.
- Assumes environmental threshold exists.

DISADVANTAGE

- Not absolute thresholds: some judgement needed.
- Some values based on very little data.
- Public may question validity.

ASSUMPTIONS

- DMEGs (Discharge Multimedia Environmental Goals) assume no dilution prior to exposure, MEGs (Multimedia Environmental Goals) based on leachate.

LIMITS

- Assumed routes of human exposure is through drinking water.

USES

- Limited use because not well known. Very useful in negotiating with State and Federal agencies.

APPROACH V

DEFINITION

Dioxin equivalencies for carcinogens: Several models have been developed to equivalate known and suspected carcinogens to 2,3,7,8-Tetrachlorodibenzo-p-dioxin. Normally the basis of these calculations is centered around a defined Potency Factor (95% confident limit for risk per unit exposure) and an acceptable 10^{-6} additional risk criteria. Using these two numbers an environmental acceptable level is calculated.

ADVANTAGES

- Systematic approach.
- Based on extrapolation of extensive toxicity data.
- Assumes Environmental Threshold exists.
- Site specific conditions used in calculations.
- Number defined in probably most reliable data available.

DISADVANTAGES

- Requires input from off-site EPA parties.
- Public often questions validity.
- Can take weeks/months.
- Bureaucracy often leads to avoidance behavior by on-site personnel.

ASSUMPTIONS

- All compounds used have same physical/chemical characteristics and behavior as 2,3,7,8-TCDD.
- 10^{-6} acceptable cancer risk.

LIMITS

- Relatively large database but still limited by defined "Potency Factors" of known and suspected carcinogens.

USES

- Widely used on non-screaming emergency responses and long term removals where extended time requirements are not a problem.

APPROACH VI

ACCEPTABLE CHRONIC INTAKE (AIC) AND ACCEPTABLE SUBCHRONIC INTAKE (AIS) CRITERIA FOR NON-CARCINOGENS

DEFINITION	AIC is defined as highest lifetime (70 years) exposure level not expected to cause adverse effects. AIS is defined as the highest short term (10-90 days) exposure not expected to cause adverse effects. Risk assessment consists of comparing listed acceptable intake values against on-site contamination levels and exposure potential.
ADVANTAGES	- Systematic. - Takes site specific conditions into effect. - Uses toxicological data to derive AIC and AIS values. - Assumes Environmental Threshold exist.
DISADVANTAGES	- On-site exposure potential must be calculated (judgement calls must be made). - Public probably will not willingly accept.
ASSUMPTIONS	- AIS/AIC values are meaningful.
ASSUMPTIONS	- AIS/AIC values defined to 59 compounds.
USES	- Rarely used but applicable, in some cases.

SUMMARY:

Unlike remedial response cleanups, emergency response cleanups are characterized by unplanned rapid multiple agency decision making.

Often times cleanup criteria resulting from this decision making is erroneous. The main reasons for these errors are ignorance of known standards, data and methodologies combines with politics.

Six commonly used or available approaches are outlined for establishing cleanup criteria.

No one approach is applicable for all incidents but knowledge of the existence of these approaches hopefully will result in better decision making in the future.

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«BONJOUR CHEZ VOUS»

Réflexions d'un citoyen sur le syndrome «NIMBY» ou «PAS DANS MA COUR».

Mesdames, messieurs, bonjour!

Je voudrais tout d'abord remercier les organisateurs de cette conférence de m'avoir invité à partager avec vous les réflexions d'un simple citoyen sur le fameux syndrome «NIMBY»

J'ai accepté avec plaisir de me joindre à vous et ce pour plusieurs raisons. Bien entendu, je suis un partisan avoué de la protection de l'environnement et j'ai aussi été, soit acteur, soit spectateur d'un certain nombre d'opérations du type «NIMBY».

C'est d'ailleurs au cours d'un de ces épisodes que j'ai fait la connaissance de Jean Godin, avec qui je partage aujourd'hui cette tribune. J'aurai l'occasion de revenir sur ces expériences particulières un peu plus tard, au cours de la période d'échange.

J'ai intitulé mon commentaire «Bonjour chez vous». C'est un titre qui m'a été inspiré par la série britannique «Le Prisonnier». Vous vous souviendrez sûrement du numéro 6, prisonnier dans un village toujours dirigé par un nouveau numéro 2, relevant d'un numéro 1 toujours inaccessible.

Cette expression, «Bonjour chez vous», illustre l'ironie de la situation vécue par ceux et celles qui reçoivent dans leur cour une cargaison de déchets sans savoir d'où elle vient ou qui a pris la décision. Ils ont toujours affaire au numéro 2. «Bonjour chez vous» illustre aussi le cynisme de ceux qui préfèrent envoyer leurs déchets ailleurs plutôt que de régler le problème chez eux. Ceux-ci appliquent le raisonnement qui veut que ce que l'on ne voit pas ne peut nous faire de mal.

Passons donc maintenant à l'essentiel du sujet.

La dernière décennie a marqué l'émergence de plus en plus accélérée de courants sociaux préoccupés de protection de l'environnement. Longtemps perçus et traités comme d'inoffensifs poètes, par ailleurs fort sympathiques, les pionniers de l'environnement comme Pierre Dansereau ou Frédéric Back occupent maintenant l'avant scène. Se sont joints à eux une multitude de personnes et d'organismes tout aussi préoccupés, du moins l'espère-t-on, de la sauvegarde de notre écosystème.

Fouettés par les récentes catastrophes comme Love Canal, Three Mile Island, Bhopal, Tchernobyl, l'Exxon Valdez ou, plus près de nous, la Balmet ou St-Basile Le Grand, les voix se font de plus en plus stridentes et de moins en moins conciliantes.

Le moins que l'on puisse dire, c'est que la confiance ne règne pas dans le merveilleux monde de la protection de l'environnement. «I think - Should I say it? - I think that's bullshit. I really do, I think it is. "Everything's under control". Bullshit. Nothing's under control. I don't believe anything they say, if you want to know the truth. I do not beleive anything I hear from them»(1). Ainsi s'exprimait, plutôt crûment, une dame d'un certain âge lorsqu'interrogée sur ses sentiments à propos de la gestion de la catastrophe de Three Mile Island. Et c'est un sentiment que l'on peut ressentir à peu près partout maintenant.

Pourquoi le «NIMBY»? Probablement, je dirais même très certainement, à cause de cette cassure dans la relation de confiance. Perte de confiance, d'abord dans la capacité de la science de contrôler ses propres créatures. Ce que j'appellerais le syndrome de l'apprenti sorcier. Perte de confiance, ensuite, dans les leaders industriels dont l'appât du gain semble être la principale sinon la seule motivation. On n'a qu'à voir comment ils se convertissent maintenant à l'écologie pour s'en convaincre. Perte de confiance, enfin, dans les leaders politiques dont les valses-hésitations et les atermoiements, sans oublier les cachotteries, suffisent amplement à semer le doute.

(1) Erikson, Kai. Toxic Reckoning. Business Faces a New Kind of Fear. Harvard Business Review. Jan. Feb. 1990

Vous ajoutez à cela les approches démagogiques et égoïstes frisant souvent l'hystérie utilisée par certains «self appointed leaders» et vous avez tous les ingrédients pour empêcher toute solution rationnelle, qu'elle soit globale ou sectorielle, à des problèmes qui ne laissent désormais personne indifférent.

«PAS DANS MA COUR» «POURQUOI MOI?» «Je ne suis pas responsable (ou si peu) du problème». «Pas question que je paye pour l'incurie des autres». Or, justement, nous sommes toujours «l'autre» de quelqu'un. C'est un fait que nous oublions souvent et qui vaut pour toute situation. Que l'on parle de l'élimination des déchets toxiques, de l'implantation de maisons de transition ou d'accueil, ou encore d'aménagement urbain, le syndrome se manifeste invariablement.

Comment donc gérer ce syndrome du «PAS DANS MA COUR»? Bien sûr, nous pouvons toujours prendre le problème à sa source même et ne pas produire de pollution. Or, dans une société comme la nôtre, il y a ce que les américains appellent des «trade-offs» à faire. Ces «trade-offs» ou compromis résultent du développement de notre société. Il n'existe pas de développement possible sans un certain prix à payer. Le tout est de viser un équilibre optimal. À moins de revenir au nomadisme et à l'économie de subsistance, nous devrons continuer d'envisager ces fameux «trade-offs», donc en bout de piste, une certaine pollution.

Nous pourrions aussi resserrer les contrôles sur les compagnies polluantes tout en leur appliquant la politique du GLYDBY, soit le «go live in your dirty backyard». Imaginez la célérité avec laquelle les dirigeants de la Balmet auraient nettoyé leur cour plombée si on les avait tirés de leur banlieue cossue pour les installer pendant six mois dans une roulotte à l'arrière de leur usine de St-Jean. Je n'invente rien ici. Je m'inspire plutôt d'une décision d'un juge américain qui avait condamné un riche propriétaire de taudis à aller vivre dans un de ses propres logements. Cela équivaut au bon vieux truc du «nez dedans» utilisé par mon voisin pour convaincre son jeune chien de faire ses «dépôts» au bon endroit.

Toutes ces mesures ne suffiraient quand même pas, d'une part, à régler le problème accumulé (ou le back-log) ni, d'autre part, à régler ce qui resterait forcément, même si nous éliminions au maximum la pollution à la source même. Que nous le voulions ou non, le «NIMBY» demeurera présent. Autant en prendre son parti. Que faire alors ?

Dans un premier temps, il faut accuser réception du phénomène et en accepter la légitimité. Plusieurs intervenants ont tenté soit d'ignorer la question ou de bousculer l'opposition. D'autres ont tenté de savantes approches de marketing, destinées beaucoup plus à faire

passer la pilule qu'à vraiment prendre en compte les besoins et les sentiments des gens. Toutes ces approches sont vouées à l'échec à plus ou moins long terme. Dans l'état actuel des choses, je vois trois conditions fondamentales pour une gestion intelligente du syndrome «nimby».

Premièrement, la transparence. Partant du principe que tout se sait un jour ou l'autre, pourquoi tenter de dissimuler les problèmes, les décisions ou les faits et gestes des intervenants ayant un impact sur l'environnement? Je suis un tenant du principe que si les citoyens sont capables de voter, ils sont capables de comprendre les tenants et les aboutissants des questions qui les concernent. Cessons de nous gargariser de principes démocratiques alors que nous cachons aux principaux intéressés les faits qui les concernent. La dissimulation ne fait qu'augmenter la méfiance, exagérer les réactions et diminuer, sinon faire disparaître, toute possibilité de collaboration ultérieure.

Dès que nous enclenchons un processus à partir de positions fondées sur la méfiance et le manque de transparence, nous nous plaçons en situation de guerre. Or, dans une guerre, il faut qu'il y ait un perdant et un gagnant. Dans de tels cas, peu importe le gagnant, on peut croire que l'intérêt général soit globalement perdant de cette passe d'armes.

Deuxièmement, la consultation, et encore selon un processus ordonné et respectueux des intervenants. Il faut éviter à tout prix les opérations de rattrapage bâclées à postériori et uniquement destinées à sauver la face. Les gens ne sont pas dupes. Le marketing malhabile ne sert qu'à élargir encore plus la brèche dans la confiance. Il faut aussi éviter les débats de spécialistes. Dans ce quatrième colloque sur les substances toxiques, il est intéressant de constater la place dans la grille horaire qui a été réservée au «nimby» ainsi que le temps qui a été alloué au seul et unique représentant des citoyens. Heureusement que je parle vite.

Troisièmement, et c'est probablement la condition la plus importante, la bonne foi de TOUTES les parties, y compris, et je dirais surtout, des citoyens porteurs du syndrome. Si les gouvernements et les industries réussissent l'épreuve de la transparence et de la consultation, il faut, en outre, que la bonne foi soit présente partout.

Il n'est pas rare de voir des gouvernements ou des industries tenter le coup de la séduction. Il n'est pas rare non plus de voir d'autres intervenants utiliser une cause, quelle qu'elle soit, comme tremplin vers autre chose. Les observateurs en viennent même à trouver cela normal. Il n'est pas rare non plus, comme je le disais précédemment, de voir des intervenants aux trois paliers qui envisagent une intervention comme un combat à finir avec, obligatoirement, un gagnant et un perdant. C'est ce qui explique souvent les excès de langage, les prises de position tonitruantes, exagérées et parfois même inutilement alarmistes.

Sans bonne foi, les solutions ne sont pas possibles. Sans acceptation de la réalité, sans «trade-offs», il n'y a pas non plus de solution possible. Les solutions passent par la reconnaissance du problème, entre autres par l'acceptation du fait qu'il n'y a personne, absolument personne qui soit autorisé à dire que lui ou elle n'a rien à voir avec le problème et que, par conséquent, sa cour doit demeurer à l'écart et vierge de toute retombée.

Je vous remercie.

LE NIMBY, UN PRODUIT DE LA SOCIETE D'INFORMATION

par

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INTRODUCTION

Le NIMBY paralyse certains secteurs d'activités de notre société, présentement. Il monopolise beaucoup trop d'énergie, provoque des bouleversements sociaux très intenses, des coûts directs très élevés (on parle de 500 milliards $ strictement pour l'implantation du nucléaire aux États-Unis)(1). Il a même des effets insoupçonnés sur le prestige de la technologie québécoise sur le plan international. Un représentant de notre firme localisée à Singapour nous informait des difficultés qu'il avait à faire la commercialisation de nos technologies suite à l'envoi de nos BPC en Angleterre. Je n'accepte pas que nous puissions démontrer notre capacité d'aller sur la lune et par contre, demeurer incapables de résoudre des problèmes de relations et communications socio-politiques. Il faut, de toute urgence, que nos sciences sociales rejoignent le niveau de nos compétences techniques(2).

Notre analyse doit donc porter sur les principales caractéristiques de la société d'aujourd'hui.

Mon hypothèse stipule que la SOCIÉTÉ D'INFORMATION dans laquelle nous vivons présentement comporte des changements importants qui nécessitent pour nous de nouveaux comportements et attitudes. Sans cela, nous continuerons à être confrontés à des problèmes, tel que le NIMBY. La SOCIÉTÉ D'INFORMATION caractérisée par l'omniprésence des media et des communications a des conséquences importantes par la démocratisation du processus politique, par une "complexification" du processus d'administration publique et par l'obligation de l'entreprise privée à être plus imputable socialement. Il faudra agir à la fois dans chacun de ces secteurs pour réussir à maîtriser un phénomène comme le NIMBY.

1.0 LE NIMBY

1.1 DÉFINITION

Le NIMBY, c'est l'incapacité pour les entreprises, les gouvernements, les media et les citoyens de s'adapter aux nouveaux comportements et aux nouvelles valeurs et exigences de la SOCIÉTÉ D'INFORMATION.

Il s'agit de comportements individuel et collectif devant l'implantation d'équipements ou services qui se manifestent comme suit:

a) un sentiment d'injustice sociale à l'effet qu'une communauté doit supporter les responsabilités d'une autre communauté et/ou d'une plus large. Je fais ici abstraction des considérations où, pour des facteurs techniques et d'économie d'échelle, l'on doit accepter des équipements de taille minimale.
   Ex.: Les gens de Baie-Comeau qui refusent les BPC de Saint-Basile;

b) un sentiment d'humiliation et de dévalorisation sociale car cette communauté est pointée du doigt et perçue comme de seconde classe dans les media et sur la place publique.
   Ex.: Les Britanniques qui s'exclament "Nous ne voulons pas être la poubelle du monde";

c) un sentiment de crainte et d'inquiétude basé sur un manque

d'information scientifique crédible ou tout simplement factuelle et complète.
Ex.: Les 6,000 signataires d'une pétition s'opposant à la venue de Stablex à Blainville sans avoir obtenu toutes les informations scientifiques;

d) un sentiment de non confiance envers les administrations publiques, les administrations privées et les élus.
Ex.: Le refus des citoyens d'accepter les études d'impact dans le projet d'usine d'épuration des eaux usées de la Communauté Urbaine de Québec;

e) un sentiment de force que représente l'opinion publique pour participer au processus décisionnel public.
Ex.: Opposition des citoyens au projet de réutilisation des résidus organiques dans des fours à ciment à Joliette;

f) un sentiment de perte potentielle de valeurs immobilières et de ralentissement du développement général de la communauté.
Ex.: Crainte des citoyens d'une perte de valeur de leur maison à la venue de Stablex à Blainville; et
les citoyens de Varennes s'opposant à la venue de Soligaz;

g) un sentiment d'opposition devant des erreurs d'aménagement du territoire.
Ex.: Les citoyens de Mirabel opposés au choix du site et à l'étendue des terrains expropriés;

h) un sentiment d'opposition devant l'implantation d'un projet ou d'une technique non sécuritaire.
Ex.: La disposition des déchets bio-médicaux dans des sites d'enfouissement traditionnels;

i) un sentiment d'opposition devant des processus autoritaires, des administrations publiques et privées.
Ex.: Les gens de South Cayouga en Ontario s'opposant à l'implantation d'un centre moderne de traitement des résidus industriels;

j) un sentiment d'opportunisme ou de partisanerie politique.
Ex.: La mairesse d'une ville de Nouvelle-Écosse, pour se faire élire, s'est opposée à un site d'enfouissement. Elle confirmait plus tard que le site finalement choisi était de qualité inférieure à celui dans sa cour auquel elle s'était opposée[3].

1.2 LES CAUSES

Je dois dire au départ que pour moi, le NIMBY est souvent attribuable à des négligences des entreprises et des gouvernements. Je comprends très bien une communauté qui s'oppose à la venue chez elle d'un équipement qui n'est pas démontré comme sécuritaire, qui est mal localisé selon le zonage et l'aménagement du territoire, qui est proposé par un promoteur non crédible et non transparent et qui n'a pas fait l'objet de la part des administrations publiques d'un processus d'information, de consultation et de participation, mais ces causes relativement évidentes ne suffisent pas à expliquer l'ampleur du phénomène NIMBY.

Dans la recherche de causes pour expliquer le NIMBY, il faut aussi dépasser les phénomènes de résistance au changement que l'on a observés à travers l'histoire devant l'évolution de la technologie, tel les Luddites qui détruisirent les moulins au 19e siècle en Angleterre ou les citoyens d'Hazeltown aux États-Unis qui votèrent par référendum contre le remplacement du gaz par l'électricité. C'est en examinant la société d'aujourd'hui que nous pourrons identifier les caractéristiques et les facteurs qui favorisent le développement rapide et fréquent du NIMBY. Or, ce qui caractérise la société d'aujourd'hui, c'est l'envahissement des technologies de communication, d'information et de la connaissance, qu'on a résumé sous le vocable de SOCIÉTÉ D'INFORMATION.

La SOCIÉTÉ D'INFORMATION, selon Toffler qui a écrit "La 3e Vague" et Naisbit qui a écrit "Megatrends", accélère le rythme de notre évolution et rend complexe la compréhension des phénomènes sociaux. L'information, dont sa diffusion dans tous les sens est facilitée par les technologies modernes, serait le facteur déterminant de cette transformation sociale. Les media, parmi les divers réseaux d'échanges, seraient prépondérants dans ces grands mouvements. Examinons de plus près les media pour mieux saisir leurs interactions et relations avec la réalité quotidienne.

1.2.1 LES ACTIVITÉS MÉDIATIQUES

L'on pourrait se poser la question suivante: "Watergate et les événements de démocratisation de l'Europe de l'Est auraient-ils eu lieu sans l'existence des media?" Andrew Simon, de Radio-Canada International, attribuait aux media un rôle important dans l'accélération de l'histoire des pays de l'Est.

Impact non encore soupçonné et évalué, les media sont eux-mêmes en constante évolution et s'interrogent sur leur façon de faire. Walter Cronkite regrettait l'action partielle des grands réseaux de télévision qui ne diffusaient que des manchettes. D'autres études révèlent que le citoyen moyen regarde la nouvelle, il ne la lit pas[4]. Récemment, une dizaine de personnalités invitées à donner un avis au Conseil de presse du Québec déclaraient "l'information se devrait être de la formation"[5].

Quoiqu'il est difficile de mesurer les types d'impacts négatifs ou positifs des media, nous pouvons toutefois constater l'omniprésence des media et leur rapidité d'action. Ex.: (un journaliste américain, dans son bureau à Washington, à quelques pas d'où avait lieu la tentative d'assassinat du Président Reagan, apprenait l'incident par un appel téléphonique de son bureau de Londres).

Si le citoyen des sociétés passées était alimenté par le curé, sa famille et les notables, par après, par les journaux, la radio et la télévision, Toffler nous dit qu'aujourd'hui "le citoyen est assailli par des fragments d'images contradictoires ou décousues qui ébranlent nos vieilles idées, nous mitraillent sous forme de "blips" incohérents ou désincarnés"[6].

A cet égard, le citoyen est souvent dépourvu devant la nouvelle. Laissez-moi vous donner quelques exemples dans le domaine qui nous concerne, soit l'environnement.

1.2.1.1 L'EAU

La Presse, 20 janvier 1989 titre "l'eau minérale naturelle est dangereuse". Or, la population a augmenté la consommation d'eau minérale lorsque des nouvelles lui indiquant que l'eau distribuée par plusieurs municipalités était non propre à la consommation.

1.2.1.2 LES RAISINS DU CHILI

Time Magazine, Mars 1989

Des gens croyant être empoisonnés par les raisins du Chili attendaient pendant des heures l'examen du médecin. Lorsqu'on leur a dit que le cyanure suspecté dans le raisin agissait en-deça d'une à deux minutes, ces gens comprirent que leurs maux d'estomac et de tête étaient artificiels car ils avaient consommé le raisin 3 jours auparavant.

Cette panique avait causé une perte de plusieurs millions et effrayé tout un continent. La quantité de cyanure trouvée dans un raisin était si petite que le maximum qu'elle pouvait causer était quelques colliques à un bébé.

1.2.1.3 LES LÉGUMES

L'oeil régional, 20 août 1989

"L'incendie de l'entrepôt de BPC de Saint-Basile: moins dangereux

que les légumes du marché".

1.2.1.4 **LES COUCHES JETABLES**

L'Actualité du mois de novembre 1989 titre "Les couches jetables de papier non blanchi sont-elles écologiques?" Oui, dit Pollution Probe; Non, dit Greenpeace. "Les couches de coton réduisent les déchets à enfouir, mais leur lavage demande une plus grande dépense d'énergie sans compter le détergent."

1.2.1.5 **LA POMME DE TERRE**

La Presse, 25 novembre 1989

"Tout ce que nous mangeons contient du poison. La nature crée ses propres agents chimiques; la pomme de terre en contient en moyenne 150."

1.2.1.6 **L'ATMOSPHERE**

Time Magazine, Novembre 1989 et La Presse, 27 janvier 1990

Selon la théorie GAIA du scientifique Lovelock, le niveau d'oxygène est demeuré stable dans l'atmosphère depuis 200 millions d'années stabilisant ainsi la température, ceci par une fonction d'ajustement entre la terre et les autres planètes. Le World Watch Institute déclarait le contraire "la composition chimique de l'atmosphère est très différente de ce qu'elle était il y a à peine 150 ans".

1.2.1.7 **ADDITIF ALAR SUR LES POMMES**

Time Magazine, Décembre 1989

Selon Bruce Ames, un biologiste de l'Université de Californie, le produit Alar, décrit par plusieurs comme toxique, est moins dommageable que plusieurs fruits qui, sans additifs, contiennent 1,000 fois plus d'éléments carcinogènes.

Il apparait évident que les media peuvent avoir un rôle important d'information et les gouvernements et entreprises qui oeuvrent constamment avec les divers publics devront tenir compte de cette réalité.

CETTE OMNIPRÉSENCE DES MEDIA PEUT EXPLIQUER COMMENT LE NIMBY PEUT RAPIDEMENT DEVENIR UN SUJET PUBLIC. EN EFFET, LES PRÉOCCUPATIONS AU SUJET DE L'IMPLANTATION D'UN ÉQUIPEMENT PASSENT RAPIDEMENT DE QUELQUES CITOYENS A TOUTE LA COMMUNAUTÉ LOCALE. DE LA, LE SUJET EN QUESTION N'A PLUS DE FRONTIERE. DANS UN TEL CONTEXTE, LA COMMUNAUTÉ EST POINTÉE DU DOIGT PUBLIQUEMENT COMME L'ONT ÉTÉ SENNETERRE, SAINT-BASILE, L'ANGLETERRE ET BAIE-COMEAU DANS LE CAS DES BPC.

1.2.2 **DÉMOCRATISATION POLITIQUE**

Un deuxième impact important de la SOCIÉTÉ D'INFORMATION se manifeste au niveau politique. Selon Marshall McLuhan, l'ère électronique nous implique malgré nous dans de grands phénomènes sociaux. La nouvelle société est décentralisée en terme de forces politiques mais reliée par l'information. Toffler et Naisbit, tous deux, s'accordent à dire qu'une des plus grandes conséquences de la SOCIÉTÉ D'INFORMATION est la décentralisation du pouvoir politique. Le pouvoir est partagé avec des groupes d'intérêts minoritaires mais très actifs, dont le système électoral est dépassé par des activités de représentation et d'échanges entre les périodes électorales. Aux États-Unis, 25 % des citoyens appartiennent à des groupes participant au processus de décision politique[7]. Soucy D. Gagné, de SORECOM, déclarait récemment que l'opinion publique est devenue une force consciente d'elle-même et peut, grâce aux media, faire des choix stratégiques[8]. Léon Dion, politicologue bien connu, énonçait cette hypothèse depuis déjà quelques années.

Il faut donc modifier notre compréhension du système politique et élaborer des façons de faire qui en tiennent compte.

LE NIMBY, CONSTATÉ DANS LE MOUVEMENT D'OPPOSITION A L'IMPLANTATION D'UN CENTRE DE TRAITEMENT DES RÉSIDUS INDUSTRIELS A SOUTH CAYOUGA

EN ONTARIO ÉTAIT, SELON UN SPÉCIALISTE A LA CONFÉRENCE SUR LE NIMBY A YORK UNIVERSITY EN 1984, DU A L'ABSENCE DE DÉMOCRATIE DES ÉLUS ET DES FONCTIONNAIRES DANS LE PROCESSUS. LA LITTÉRATURE ABONDE DE CAS OU LES ÉCHECS D'IMPLANTATION SONT DUS A L'ABSENCE D'IMPLICATION DES CITOYENS ET GROUPES, TOT DANS L'IMPLANTATION. L'engagement des élus, leur transparence et leur présence sont des éléments importants pour établir une confiance entre la population et eux. Dans le cas où le NIMBY a été contré, les élus ont joué un rôle primordial pour rendre crédible les projets des administrations publiques et privées. Le citoyen d'aujourd'hui, plus scolarisé et plus informé, souhaite participer au processus décisionnel lorsqu'il se sent directement touché.

Nous verrons dans les solutions proposées comment innover sur le plan des structures politiques et comment modifier nos attitudes pour sérieusement s'attaquer au NIMBY.

1.2.3 COMPLEXITÉ DES ADMINISTRATIONS PUBLIQUES

S'il y a décentralisation effective du système politique, les administrations publiques sont aussi affectées par ses mouvements de la base, de densification des populations et interaction des systèmes sociaux. L'adaptation est plus difficile compte tenu de la complexité et la taille des administrations publiques. L'urbanisation et les échanges ont nécessité des interventions de l'état en terme de lois et réglementations. Selon des études, les informations techniques sont plus facilement diffusées que les informations sur les lois et règlements[9]. Il semblerait que les institutions conçues pour un rythme plus lent sont incapables de décider aussi rapidement que l'exigent les événements. Un exemple peut illustrer les difficultés des administrations publiques à gérer des problèmes reliés à l'environnement: après que GM eut dépensé 800 millions $ pour se conformer aux normes gouvernementales, le gouvernement annonce que les voitures ainsi équipées émettent 35 fois plus d'acide sulfurique qu'avant[10].

Le cas de l'amiante où des études récentes faites par des experts américains concluaient à l'absence de risque est illustrateur à cet égard. Les normes vont représenter des coûts énormes à la société tant que les législations ne seront pas changées. La revue Time du 29 janvier 1990 nous indiquait que le risque de mourir par la cigarette, la noyade ou en jouant au football est 100 à 1,000 fois plus élévé que d'être exposé à l'amiante dans un édifice.

Le grand spécialiste de l'administration américaine, Yehezkel Dror, déclare que les administrations publiques doivent aujourd'hui gérer des situations beaucoup plus complexes résultant d'une accélération technologique et d'une évolution sociale rapide. Il propose une plus forte participation des citoyens, une présence du monde universitaire, un enrichissement des responsabilités des fonctionnaires et une propension à l'action[11].

LE NIMBY RÉSULTE SOUVENT D'ABSENCE DE PROCESSUS OUVERT ET ADÉQUAT DE SÉLECTION DE SITE, DE PARTICIPATION DES CITOYENS DANS L'ÉLABORATION DES DEVIS D'ÉTUDES D'IMPACT ET DANS LA RÉALISATION DES ÉTUDES. DES IMPROVISATIONS ONT SOUVENT CAUSÉ DES DIFFICULTÉS DE LOCALISATION D'ÉQUIPEMEMENTS DANS DES PARCS INDUSTRIELS. CES PARCS ÉTAIENT INAPPROPRIÉS ET N'AVAIENT AUCUN ACCES ROUTIER CONVENABLE.

ON A SOUVENT VOULU IMPOSER A UNE COMMUNAUTÉ LA RESPONSABILITÉ DE SUPPORTER SEULE DES ÉQUIPEMENTS RÉGIONAUX SANS ASSURER DES MESURES DE MITIGATION ET DE COMPENSATION ACCEPTABLES.

1.2.3.1 CONTRIBUTION DU MONDE SCIENTIFIQUE

L'absence du monde scientifique pour donner un éclairage aux divers intervenants impliqués dans nos processus sociaux est une cause importante du développement du NIMBY. Une des grandes craintes des citoyens repose sur l'imprécision des évaluations des procédés, des

techniques, de leurs impacts et des risques.

Selon le Dr. Francis M. Gaddis de Columbia University, qui a effectué une recherche importante sur les critères de sélection, une des deux principales recommandations concerne le monde scientifique: "A call to the scientific community to become more involved in the decision making processes and collectively provide support through their professional societies and academic institutions for the exercise of their societal responsibilities"[12].

Selon Desmond M. Connor, spécialiste en concertation sociale, l'Université de Toronto a joué un rôle important pour dédramatiser la question des BPC dans la région de Toronto.

Selon Paul Slovic[13] dans la revue Science, Vol. 236, 17 avril 1987, les craintes sont déterminées par la non compréhension de la situation. Un accident de train inspire moins de crainte qu'un laboratoire de recherches sur l'ADN qui apparait comme mystérieux.

Il cite le scientiste A. Wildawsky qui indiquait qu'il y a aujourd'hui plus de risques au sujet d'une forte quantité d'anciens petits barrages que des réacteurs nucléaires. Or, les citoyens s'opposent fortement au nucléaire mais ne s'inquiètent pas des barrages.

Il ajoute que les études sont aussi assez éloquentes sur la perception des risques: plus les personnes sont formées scientifiquement, moins ils perçoivent comme dangereux divers éléments perçus comme à risque dans la population.

Slovic ajoute qu'une étude indique que les gens acceptent facilement les risques de faire du ski, 1,000 fois plus dangereux, que les préservatifs dans la nourriture et qu'il est autant dangereux de conduire sur une distance de trois milles que d'habiter à côté d'une centrale nucléaire.

La revue Time, qui couvrait l'incident des raisins du Chili, indiquait que les experts déclaraient qu'il était beaucoup plus risqué d'être frappé par une voiture en se rendant au centre d'achats pour acheter ces raisins que de les manger.

Finalement, Henry. I. Balker, directeur de la recherche à l'Institut canadien des pâtes et papiers, déclarait récemment que l'ignorance de la science résulte en soupçons et peurs[14].

La contribution du monde scientifique peut se manifester de diverses façons. Premièrement, comme expertise neutre et objective à laquelle peuvent faire appel les gouvernements, les media, les groupes écologiques, les entreprises et les citoyens. L'inquiétude des citoyens, dans l'implantation des usines des eaux usées, attribuée à un manque d'information scientifique, s'est modifiée suite à des ateliers de travail auxquels participaient médecins, toxicologues, ingénieurs et chimistes.

UNE DES GRANDES CAUSES DU NIMBY REPRÉSENTÉE PAR DES SENTIMENTS DE CRAINTE ET D'INQUIÉTUDE EST ATTRIBUABLE AUX DIFFICULTÉS QU'ONT LES MEDIA ET LA POPULATION A OBTENIR DES INFORMATIONS CLAIRES ET SIMPLES POUR LES GUIDER DANS LEURS ÉVALUATIONS DU RISQUE ET COMPRÉHENSION DES ÉLÉMENTS DES PROJETS.

1.2.4 L'IMPUTABILITÉ SOCIALE DES ENTREPRISES PRIVÉES

En 1990, le terme "privé" n'est plus adéquat pour décrire l'entreprise privée car aujourd'hui, aucune activité économique ou commerciale ne peut être vraiment privée.

La SOCIÉTÉ D'INFORMATION amène aussi des changements dans le fonctionnement des entreprises privées. Une cause majeure dans l'implantation de projets est la crédibilité des entreprises. Le citoyen, au départ, ne fait pas confiance à l'entreprise et souvent, refuse l'échange avec ses représentants.

Gerald Clay de l'entreprise Star-Kist admet que lors de l'événement du poisson avarié, il eut été préférable de s'ouvrir à la population.

Johnson & Johnson, lors de la crise Tylenol, procédait d'une façon tout à fait différente et réussissait à récupérer leur marché[15].

LA NÉGLIGENCE DE CERTAINES ENTREPRISES DE BIEN PRÉSENTER LEUR PROJET, D'UTILISER UNE TECHNOLOGIE ÉPROUVÉE, D'ETRE DISPONIBLE POUR LES GOUVERNEMENTS, LES MEDIA, LES GROUPES ET LES CITOYENS A SOUVENT CRÉÉ DES NIMBY. QUI ACCEPTERAIT, DANS SA COUR, LES CONDITIONS MÉDIOCRES D'ENTREPOSAGE DE BPC?

1.3 LE CAS DES BPC

Je n'analyse pas ici la période reliée directement au NIMBY à Senneterre. Mon collègue Alain Sauriol est mieux placé pour le faire. Mon analyse porte sur quelques mois avant les élections provinciales du 25 septembre 1989, pendant les élections et quelques mois après.

1.3.1 AVANT LES ÉLECTIONS

Il est intéressant de noter que du 4 octobre 1988 au 16 juin 1989, des BPC ont voyagé au Québec et du Québec en Angleterre, sans problème majeur.

La Presse, 4 oct. 88	"11,000 litres de BPC du Nouveau-Brunswick arrivent à Montréal".
La Presse, 8 juin 89	"110 tonnes de BPC expédiées en Angleterre le 1er juin 1989".
La Presse, 8 juin 89	"215 tonnes de BPC expédiées en Angleterre".
La Presse, 16 juin 89	"Hydro-Québec expédie 120 tonnes de BPC en Grande-Bretagne". Dans cet article, on rapporte que les employés du port s'étonnent de l'intérêt porté aux BPC par les media. Ils estiment que des matières beaucoup plus dangereuses sont manipulées tous les jours dans le port, sans qu'on y prête attention.
La Presse, 19 juin 89	"L'UPA et les centrales syndicales déboursent 40 000 $ pour contrer l'incinérateur des BPC".

Jusqu'au 16 juin 1989, le NIMBY en Angleterre n'existait pas pour les BPC du Québec. Qu'est-il arrivé pour que l'Angleterre et Baie-Comeau utilisent le NIMBY pour refuser les BPC du Québec?

1.3.2 PENDANT LES ÉLECTIONS

Posons-nous les questions suivantes:

- S'il n'y avait pas eu de téléphone, ni de télévision entre l'Angleterre et le Québec, un mouvement d'opposition se serait-il développé si rapidement?
- S'il n'y avait pas eu d'élection, aurait-on acheminé les BPC de Saint-Basile en Angleterre après leur refus en Alberta?
- Si les BPC n'avaient pas déjà été refusés à Senneterre et perçus dans l'opinion publique comme un produit dangereux et non bienvenue, les Anglais se seraient-ils sentis humiliés, dévalorisés à la face du monde?

On peut se poser la même question pour les gens de Baie-Comeau.

A la première question, il est évident que la rapidité de communication facilite le développement d'un mouvement d'opinion publique. La Presse, le 11 août 1989, titrait "Greenpeace continue le combat", déclarait un porte-parole de Greenpeace rejoint à Londres par La Presse.

La partisanerie politique a aussi augmenté la couverture médiatique des BPC. Alain Dubuc de La Presse déclarait, le 31 août 1989, "que la question des BPC avait monopolisé la campagne électorale". De toute évidence, les Anglais se sont vus dévalorisés. Leurs journaux titraient "nous ne voulons pas être la poubelle du monde". Il aurait

été plus approprié pour nous de mener une campagne dynamique d'information et lancer un message international louangeant les Anglais pour leur avance technologique et leur capacité de traiter les BPC de façon sécuritaire. Le sentiment de dévaluation aurait pu être atténué.

Pour les gens de Baie-Comeau, même si la responsable de la coalition contre l'entreposage à Baie-Comeau déclarait que pour eux, les conteneurs étaient sécuritaires, c'était, selon elle, la façon dont on avait imposé cette décision, donc le processus, auquel on s'objectait.

A la dernière question au sujet d'une absence d'information scientifique comme cause du NIMBY, il faut croire que le 15 août 1989, au début de la fièvre électorale, l'article de Louis-Gilles Francoeur était écrit trop tard. "Les BPC de Saint-Basile sont inoffensifs. La crainte politique l'a emportée sur le bon sens et la raison, affirment les spécialistes". De même que les éditoriaux dédramatisants de La Presse, du Soleil, du Journal de Montréal à la même période, ils venaient trop tard. Plus particulièrement, le 8 septembre 1989, Le Devoir rapportait "Le gouvernement a amplifié le danger et aidé à créer la psychose, selon les chimistes". Ce témoignage vital pour la population aurait été beaucoup plus bénéfique un an auparavant. Le 8 septembre, nous avions atteint un point de non retour.

La notoriété de l'événement a particulièrement atteint son paroxisme au niveau des media lorsque le 24 août 1989, La Presse avait, dans une seule parution, six (6) articles sur les BPC, dont la manchette en première page:

i. "Baie-Comeau mobilise ses citoyens".
ii. "Les BPC à Manic 2: Mulroney endosse la décision de Québec".
iii. "BPC: Bourassa accuse Parizeau de fraude intellectuelle".
iv. "Un employé chargé du nettoyage des BPC est gravement blessé".
v. "Les BPC de Saint-Basile: le gouvernement accusé de se défiler".
vi. "Les BPC font route vers Baie-Comeau".

1.3.3 APRES LES ÉLECTIONS

Après la campagne électorale et le débarquement à Baie-Comeau, le calme revient.

La Presse, 17 nov. 89 — "28 barils de BPC ont quitté Montréal pour la France. Aucune opposition en France".

La Presse, 23 nov. 89 — "La cargaison est arrivée sans encombre et dans l'indifférence des media et des organisations écologiques".

Pourquoi les mêmes BPC n'ont pas créé de NIMBY en France? On peut faire l'hypothèse que le sujet avait perdu son intérêt, que l'acheminement n'était plus politisé et qu'il ne pouvait devenir sujet important de discussions publiques.

De la même façon, La Presse nous informait, le 17 septembre 1989, "Des BPC voguent sans histoire". "Un chaland chargé de 400 tonnes de BPC est arrivé hier à Goose-Bay sans, toutefois, donner lieu à des protestations comme cela avait été le cas lors de l'arrivée de cargaison similaire à Baie-Comeau".

On pourrait faire l'hypothèse que l'isolation de Goose-Bay et l'absence d'activités politiques intenses chez eux à cette période sont des facteurs qui ont empêché le développement du NIMBY.

Sans aucun doute, nous avons ici plusieurs bons sujets de thèse en sciences politiques, communications, journalisme, administration publique, etc...

1.4 SOLUTIONS

1.4.1 LES CONDITIONS PRÉALABLES

- DES ÉQUIPEMENTS ET PROCÉDÉS SÉCURITAIRES SANS NUISANCE DE TOUT ORDRE: VISUELLE, D'ODEUR, DE BRUIT, DE TRANSPORT ET DE CONTAMINA-

TION AIR, EAU, SOL.

- DES ENTREPRISES QUI ACCEPTENT LES NOUVELLES REGLES DE FONCTIONNEMENT DE LA SOCIÉTÉ D'INFORMATION QUANT A LEUR OUVERTURE.
- DES CRITERES DE SÉLECTION DE SITES VALIDÉS AUPRES DES COMMUNAUTÉS VISÉES.
- DES MEDIA QUI RECHERCHENT UNE OBJECTIVITÉ MALGRÉ LEUR DOUBLE ROLE CARACTÉRISÉ PAR LA NÉCESSITÉ DE DONNER DE L'INFORMATION ET EN MEME TEMPS, DE FAIRE DES AFFAIRES.
- DES SITES QUI RESPECTENT UN ÉQUILIBRE ENTRE LE PRINCIPE QUE CHACUN DOIT ASSUMER SES RESPONSABILITÉS SOCIALES DANS LE TRAITEMENT DES DÉCHETS ET CELUI QUE LES FACTEURS ÉCONOMIQUES, TECHNIQUES ET DE SÉCURITÉ DOIVENT DÉTERMINER LA TAILLE DES ÉQUIPEMENTS DE TRAITEMENT.
- DES ADMINISTRATIONS PUBLIQUES ET DES ENTREPRISES QUI ACCEPTENT QUE LE SYSTEME POLITIQUE D'AUJOURD'HUI EST CARACTÉRISÉ PAR UNE DÉMOCRATIE PLUS INTENSE DÉPASSANT LE VOTE PÉRIODIQUE.
- DES SCIENTIFIQUES QUI S'IMPLIQUENT A TOUS LES NIVEAUX.
- DES PHILOSOPHIES ET VALEURS ORIENTÉES VERS LA MÉDIATION ET LE COMPROMIS ET NON LA CONFRONTATION.
- DES ADMINISTRATIONS PUBLIQUES ET PRIVÉES PROACTIVES.
- DES ÉLUS AVEC VISION ET LEADERSHIP.

Une recherche m'a permis d'identifier en Europe, aux États-Unis et au Canada, des cas succès où le NIMBY a été bien géré. J'ai retouvé dans chacun des cas à succès les mêmes principes et méthodes. Je vous les livre:

1.4.2 CAS A SUCCES

a) L'implantation d'un centre de traitement intégré des déchets, le Gulf Coast Waste Disposal Authority's Facility, au Texas

Selon le Dr. M. Francis Gaddis, les deux principales stratégies utilisées sont: Implication des media et Implication du milieu comprenant le monde scientifique, la Chambre de Commerce et les groupes communautaires locaux dans un processus de planification publique, le Texas Keystone Plan[16].

b) L'implantation d'un centre de traitements dans la petite ville de Nyborg au Danemark

Selon la revue Waste and Pollution Control, les éléments de succès sont: collaboration gouvernementale et secteur privé avec retombées économiques en attirant de nouvelles industries dans le parc industriel pour profiter de ces équipements de dépollution; et participation de tous les intervenants du milieu[17].

c) Relocalisation, en 1982, d'un hameau de la communauté rurale de Keephills située à 80 kilomètres d'Edmonton dans l'implantation d'une centrale thermique utilisant le charbon de la mine Highvale. Ceci, après qu'un autre site avait été refusé suite à l'opposition des citoyens en 1976.

Selon le directeur du projet de TransAlta Utilities Corporation, les éléments du succès furent:

i. philosophie de participation du public;
ii. étape initiale d'information complète sur les règles du jeu au tout début du projet;
iii. établissement de rapports crédibles et authentiques avec la communauté avant de procéder;
iv. connaissance des attentes, préoccupations et dimensions culturelles de la communauté;
v. comité de coordination et de liaison avec la communauté, formé de sept personnes: trois de la communauté, deux de TransAlta et deux de la MRC.

En plus, six fonctionnaires assistaient aux réunions du comité

comme aviseurs techniques;

vi. utilisation de médiateurs "conflict managers".

Selon le directeur, ce processus, quoique coûteux et long, maintient la confiance du public envers le gouvernement et les entreprises et assure l'implantation du projet[18].

d) Remplissage d'une carrière située sur l'Ile Shady près d'un village de pêcheurs, Steveston, Colombie-Britannique

Une forte opposition et la présence de 12 groupes d'intérêts impliqués dans un processus de participation publique acceptent finalement un plan proposé par un représentant des citoyens.

Selon Desmond M. Connor, consultant dans ce projet, les éléments à succès furent:

i. une bonne identification des préoccupations réelles des citoyens;
ii. l'établissement de liens avec les divers publics: citoyens, syndicats, divers paliers de gouvernements;
iii. de bons dossiers techniques sur les enjeux du projet;
iv. un plan de communication et de consultation vulgarisant les informations techniques;
v. une gestion de projet crédible, proactive, disponible et transparente[19].

e) L'implantation d'un centre intégré de traitement de résidus industriels par un comité mixte gouvernement/entreprise privée à Swann Hills en Alberta en 1986

Selon un responsable de Chem-Security qui opère le centre, M. John Richardson, et selon la consultante impliquée dans le projet, les éléments à succès furent:

i. création d'un comité de liaison avec les citoyens;
ii. plan d'information complet avec toutes les données pertinentes, objectifs, moyens, etc...;
iii. étroite collaboration avec les administrations publiques;
iv. remise systématique des informations aux media[20].

f) L'implantation d'un centre de traitement de résidus industriels inorganiques à Blainville, en 1983, par l'entreprise Stablex Canada Limitée

Une pétition de 6,000 personnes contre le projet s'est transformée graduellement en une opposition très réduite laissant dire aux media "l'ouverture de Stablex, une fête écologique".

Les éléments à succès furent:

i. l'utilisation de critères de sélection adéquats;
ii. volonté politique forte des trois paliers de gouvernement;
iii. la présence sur le terrain, à Blainville, des fonctionnaires;
iv. une philosophie de transparence, de disponibilité et d'ouverture de la part de Stablex et des gouvernements;
v. des études complètes pour répondre aux préoccupations des citoyens, ex: la glaise, le transport;
vi. la formation d'un comité de liaison avec trois citoyens nommés par les groupes communautaires;
vii. une visite d'un centre similaire par les gouvernements, les media, les citoyens;
viii. plusieurs rencontres d'information avec les media;
ix. présence d'une équipe gouvernement/entreprise lors de colloques scientifiques, kiosques publics, lignes ouvertes, variété de réunions formelles et informelles (environ 50);
x. des mesures de mitigation adéquates comme un accès à l'autoroute pour le transport des camions et en même temps, donnant une mesure de compensation en facilitant l'accès des résidents à l'autoroute. Aussi, les contributions gouvernementales pour faciliter la création d'un parc industriel;

xi. l'exercice d'un rôle proactif de la part du promoteur, de la municipalité et du gouvernement provincial. Laissons le maire de Blainville parler "au début, nous étions plutôt rébarbatifs à l'idée de l'implantation de l'usine Stablex dans notre localité. Cependant, après s'être informés plus en profondeur et avoir effectué un voyage en Angleterre, nous avons rapidement modifié notre impression. Un comité de citoyens a été formé pour suivre le dossier. Stablex a fortement contribué au développement industriel et domiciliaire. De plus, je vous ferai remarquer que l'un des plus grands projets domiciliaires est situé juste à côté de l'entreprise. J'ai été réélu par acclamation au scrutin suivant de peu l'arrivée de Stablex"(21).

1.4.3 PRINCIPES DIRECTEURS

Résumons les principes directeurs identifiés par plusieurs spécialistes à travers le monde:

a)	Utilisation de critères de sélection - adéquats	- Carolyn Konheim, consultante en environnement de Brooklyn, N.Y. - Dr. M. Francis Gaddis (op. cit.)
b)	L'implication des citoyens dans l'étude d'impact	- Carolyn Konheim (op. cit.) - International Institute for Environment and Society of the Science Center of Berlin (op. cit.) - Desmond M. Connor (op. cit.)
c)	Attitude proactive et transparence des promoteurs	- Joyce Young, consultante en consultation et médiation - Garry J. Prokop, TransAlta (op. cit.)
d)	Eviter la confrontation à tout prix	- Desmond M. Connor - Joyce Young - Planning Review, Michael M. Klepper
e)	Recherche d'un win-win	- Joyce Young
f)	Rencontre informelle avec les divers publics pour compléter le processus d'information et de consultation des audiences publiques	- Joyce Young - Garry J. Prokop, - Dr. M. Francis Gaddis
g)	Participation du public tôt dans le projet	- Joyce Young - Science Center of Berlin - Dr. M. Francis Gaddis - Carolyn Konheim - Joe Haworth, L.A. County Sanitation Districts - Garry J. Prokop
h)	Visite d'installations identiques	- Carolyn Konheim
i)	Implication du monde scientifique	- Présidente du Comité de citoyens Ste-Foy, Suzanne Drouin - Dr. M. Francis Gaddis - Yehezkel Dror
j)	Connaissance de la communauté, des préoccupations et enjeux avant de démarrer le projet	- Desmond M. Connor - Garry J. Prokop - Carolyn Konheim

k) Formation d'un comité de liaison avec les citoyens
- John Richardson, Chem-Security
- Pierre Grenier, Stablex Canada
- Desmond M. Connor
- Garry J. Prokop.

Je me suis borné à faire une liste des principes directeurs et n'ai pas traité, dans le présent texte, de méthodologie détaillée. Cela pourrait représenter un sujet intéressant pour un futur colloque. Chronologiquement, il est capital de commencer par des changements d'attitudes et de comportements avant de procéder à l'opérationnalisation des principes directeurs.

CONCLUSION

Tout intervenant, qu'il soit ministre, fonctionnaire, chef d'entreprise, professeur d'université, citoyen ou journaliste, doit comprendre son rôle dans une société intégrée par les communications et retenir ce que Marshall McLuhan disait "à la rapidité que l'information circule et augmente en intensité, les systèmes politiques ont tendance à s'éloigner d'un système de délégation et représentation à un système d'implication spontanée et immédiate de l'ensemble de la communauté dans le processus de décision publique[22]. A date, les processus d'implantation sont conflictuels, coûteux, longs et ne réussissent pas souvent. J'en propose un qui est aussi long et coûteux mais qui peut être relativement harmonieux et vous assure qu'un projet ne sera pas abandonné.

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DÉBAT: "NIMBY" OU "PAS DANS MA COUR" COMMENT LE GÉRER

La Presse

M. André Noël

Paper unavailable at time of printing

Texte non reçu au moment de mettre sous presse

APPROCHE DE GESTION DU RÉFLEXE "PAS DANS MA COUR"

4e Colloque sur les substances toxiques
Montréal, le 5 avril 1990

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Depuis une dizaine d'années, une multitude de projets tant industriels (incinérateur, site d'enfouissement), que sociaux (centre de réhabilitation, maison pour sidéens), se sont heurtés à une vive réaction de rejet de la part des populations d'accueil. Les américains furent les premiers à baptiser cette réaction de "NIMBY", contraction de l'expression "Not in my backyard". À cette expression est venue s'ajouter le mot syndrome. L'introduction de ce vocable à forte connotation pathologique introduit, comme l'a fait remarquer la commission Charbonneau, un biais fort malheureux. L'emploi de ce mot présuppose qu'il y a une maladie donc des malades. En fait, il faudrait plutôt comme l'a suggéré un intervenant lors du colloque sur le "NIMBY" organisé par la Fondation québécoise en environnement, parler du réflexe "Pas dans ma cour" plutôt que du syndrome "Pas dans ma cour".Cependant au-delà de ce problème de sémantique, se cache une réalité incontournable; le "Pas dans ma cour" est un phénomène social bien réel qui cristallise les peurs et les appréhensions des gens face à une détérioration anticipée de leur qualité de vie. Le "Pas dans ma cour n'est pas une invention de promoteurs déchuent, ce n'est pas non plus une tactique pour reporter la responsabilité sur les populations récalcitrantes, le "Pas dans ma cour" est un réflexe de défense tout à fait légitime, face à un projet qui est perçu comme une agression.

Gérer le "Pas dans ma cour" c'est avant tout tenter de le comprendre. Nul recettes miracles, nul techniques hautement sophistiquées, concoctées dans des bureaux de communicateurs-conseil ne permet de désamorcer cette réaction populaire.

Comprendre le "Pas dans ma cour" c'est reconnaître dès le départ le droit des citoyens d'intervenir dans le processus d'implantation du projet. C'est reconnaître que le projet pourra être modifié selon des recommandations issues du milieu. C'est reconnaître finalement que le projet pourrait être tout simplement abandonné si l'acceptation sociale est insuffisante.

Ces trois pré-requis reconnus, le promoteur pourra mettre en place un programme de gestion du "Pas dans ma cour" qui reposera sur les éléments suivants :

- clarté
- transparence
- interaction

La clarté consiste à expliquer d'une façon accessible à tous, les données entourant le projet. La transparence assure que tous les enjeux du projet, toutes les implications sont immédiatement mises sur la table. Finalement, l'interaction permet d'impliquer dès le début la population dans le processus d'élaboration et lui permet de jouer un rôle actif dans l'implantation du projet.

Il faut toutefois éviter le piège de la communication comme solution ultime au "Pas dans ma cour". La simple diffusion de l'information n'est pas un gage de réussite. Il faut avant tout avoir un projet solide, bien conçu dans lequel les citoyens ont le sentiment que tout n'est pas joué d'avance.

Dans une société qui perd graduellement confiance dans ses institutions politiques, dans ses agences gouvernementales, qui considère que les promoteurs sont prêts à tout sacrifier sur l'autel du profit, il devient parfois difficile d'établir un dialogue constructif. En contrepartie, les gens démontrent une volonté de s'impliquer dans le processus décisionnel. Il faut donc permettre cette implication afin qu'éventuellement, le projet devienne leur projet, qu'ils en soient des partenaires et non uniquement des témoins passifs. La clé de la gestion du "Pas dans ma cour" réside donc dans cette participation active du public.

AN INTRODUCTION TO IRPTC DATABASES

APRIL 4, 5, 1990

JIM ARGO

HEALTH AND WELFARE CANADA

A DEMONSTRATION ORGANISED TO GIVE PRACTICAL EXPERIENCE IN USING THE INTERNATIONAL REGISTRY OF POTENTIALLY TOXIC CHEMICALS (IRPTC) DATABASE.

THE DATABASE ORIGINATES WITH THE UNITED NATIONS ENVIRONMENT PROGRAM (UNEP) IN GENEVA, SWITZERLAND AND IS AVAILABLE IN CANADA THROUGH THE BUREAU OF CHEMICAL HAZARDS, CRITERIA AND MONITORING DIVISION, OF HEALTH AND WELFARE CANADA.

THE DATABASE STORES INFORMATION WHICH WILL PERMIT AN ASSESSMENT OF RISKS AND HAZARDS POSED BY CHEMICAL SUBSTANCES.

HEALTH AND WELFARE CANADA IS THE NATIONAL CORRESPONDENT FOR CANADA TO THE IRPTC.

OBJECTIVES

THE OBJECTIVES OF THE REGISTER;

1 TO MAKE DATA ON CHEMICALS READILY AVAILABLE TO THOSE WHO NEED IT;

2 TO LOCATE AND DRAW ATTENTION TO MAJOR GAPS IN AVAILABLE INFORMATION AND ENCOURAGE RESEARCH TO FILL THE GAPS;

3 TO IDENTIFY POTENTIAL HAZARDS OF USING CHEMICALS AND MAKE PEOPLE AWARE OF THEM;

4 TO ASSEMBLE INFORMATION ON EXISTING POLICIES FOR CONTROL AN REGULATION OF HAZARDOUS CHEMICALS AT ALL POLITICAL LEVELS.

SCOPE

ALL CHEMICALS COVERED BY FEDERAL AND PROVINCIAL LEGISLATION AND REGULATIONS ARE ON OR BEING ADDED TO THE SYSTEM.
THE INTENT IS TO ENSURE THAT **ALL REGULATED CHEMICALS** IN CANADA ARE DESCRIBED WITH THE REGULATIONS THAT APPLY TO THEM ARE AVAILABLE ON TH DATABASE.

INTERNATIONAL INFORMATION ON CHEMICALS IS OBTAINED FROM NATIONAL AND INTERNATIONAL INSTITUTIONS, INSTITUTES, LIBRARIES, DATABANKS, AND U.N BODIES SUCH AS THE **U.N. PROGRAM ON CHEMICAL SAFETY**

LANGUAGE OF THE SYSTEM

THE OPERATING SYSTEM OFFERS THE USER A CHOICE OF EITHER ENGLISH OR FRENCH. SEARCH TERMS, WHICH ARE MNEMONICS FOR THE FIELDS, BEAR A CLOSER RESEMBLANCE TO ENGLISH THAN FRENCH.

LOGICAL TERMS ARE TRANSLATED, i.e., "AND" BECOMES "ET".

ACCESS IS BY DATAPAC AND CAN BE MADE BY ANYONE WHO IS REGISTERED AND CAN CONNECT THEIR PC OR CLONE WITH DATAPAC.

THE DATA IS UPDATED IN GENEVA AND THE NEW TAPES INSTALLED ABOUT EVERY SIX TO NINE MONTHS.

USER FRIENDLY MENUS

THE SIGN-ON PROCEDURE ALLOWS THE CHOICE OF

USER-FRIENDLY MENUS OR

HIGHER LEVEL MINISIS COMMAND LANGUAGE

BRIEF LIST OF USEFUL COMMAND MNEMONICS

=	Initiates a search
$	Ends a search
and	Boolean operator
or	" "
CHENAM	Chemical name (Legal)
COMNAM	Common name (Legal)
RTECNO	RTEC #
CASNO	CAS NO.
AREA	Geographic Area country codes in Manual (Legal)
TYPE	of Legal Mech REC,REG
SUBST	Chemical name all other database's
STUDY	Study type CASE,DMT,EPIDM,LAB,SPILL,
GEOARE	geogr. area; all database's except legal
Browse	scrolls output of search to screen
HELP	will display a list of valid commands to be used from that point
@	commercial "at"; when used with a MINISIS prompt it will show all variants of the root

STRUCTURE OF THE DATABASE

WHENEVER POSSIBLE IRPTC USES DATA SOURCES CITED IN THE SECONDARY LITERATURE TO MAXIMISE THE RELIABILITY AND QUALITY OF THE INFORMATION INCORPORATED.

INFORMATION IS ORGANISED INTO 6 ACCOUNTS WITH 1 TO 11 DATABASE PER ACCOUNT. THE NAMES OF THE ASSOCIATED DATABASES IN THE FOLLOWING ACCOUNTS IS PLACED IN BRACKETS FOLLOWING THE ACCOUNT NAME.

	ACCOUNT NAME	DATABASE NAME
1	LEGAL	
		(LEGAL)
2	ENVIRONMENTAL FATE STUDIES	
		(PHOTODEGRADATION)
		(HYDROLYSIS)
		(OXIDATION)
		(ECOSYSTEM)
		(PATHWAYS)
		(BIODEGRADATION)
		(SORPTION)
		(EVAPORATION)
3	MAMMALIAN TOXICITY STUDIES	
		(MAMTOX)
4	IDENTIFIERS,PRODUCTION PROCESS WASTE	
		(IDENTIFIERS)
		(PRODUCTION AND TRADE)
		(PRODUCTION PROCESS)
		(USE)
		(LOSS/PERSISTENCE/RESIDUE CONCENTRATIONS IN ENVIRON.)
		(HUMAN INTAKE)
		(SAMPLING/ANALYSIS)
		(WASTE MGT.)

5 SPECIAL TOXICITY STUDIES

(INTERACTING AGENTS)

(BEHAVIOUR)

(CARCINOGENICITY)

(IMMUNOTOXICITY)

(INTERACTIONS)

(IRRITATIONS)

(MUTAGENICITY)

(NEUROTOXICITY)

(REPRODUCTION)

(SENSITISATION)

(TERRATOGENICITY)

6 CHEMBIOKINETICS

(ABSOPRTION)

(AQUATIC)

(BIOCONCENTRATION)

(EXCRETION)

(METABOLISM)

(TERRESTRIAL)

(DISTRIBUTION)

Procédé de solubilisation biologique des métaux lourds des boues résiduaires

par

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Résumé

La gestion des boues produites lors de l'épuration des eaux usées représente un des coûts majeurs du traitement des eaux usées. Comme mode de disposition, l'épandage agricole présente l'avantage d'être économique et en respect avec les cycles de l'environnement. De plus, les boues constituent d'excellents engrais et amendeurs de sol. Mais, auparavant, la décontamination de ces boues s'avère souvent nécessaire puisque les métaux lourds s'accumulent dans celles-ci. En effet, au Québec, en Ontario et aux États-Unis, la norme pour la teneur en métaux lourds des boues est dépassée dans 50% des cas.

La décontamination est faite via le passage des métaux sous forme soluble. Une séparation solide-liquide permet alors leur enlèvement des boues. Les boues traitées ainsi obtenues, peuvent être utilisées en agriculture, alors que les métaux contenus dans le surnageant sont précipités.

Les procédés de solubilisation des métaux peuvent être soit chimique ou biologique. Les procédés chimiques se sont révélés très coûteux en acide alors que les procédés biologiques sont plus économiques et facile d'opération. Les procédés de solubilisation biologique des métaux sont assurés par les bactéries du genre Thiobacillus. Celles-ci en oxydant le fer et/ou le soufre et en produisant de l'acide sulfurique, permettent aux métaux de passer sous une forme soluble en milieu acide et aérobie.

À l'INRS-Eau, au cours des dernières années, l'étude de la solubilisation des métaux effectuée par les thiobacilles a permis l'optimisation du procédé. La solubilisation des métaux dans les boues anaérobies peut être effectuée dans un réacteur en continu avec recyclage (20%), en 0,75 jour avec 91% du Cu, 94% du Zn et 93% du Mn solubilisé. La consommation d'acide est 5 fois moindre que dans le cas des procédés chimiques, avec 0,072 g H_2SO_4 conc./g de boue sèche traitée.

La quantité d'azote total trouvée dans les boues avant et après traitement reste la même, alors qu'il y a une diminution de $N\text{-}NH_4^+$ après le traitement. L'azote amoniacal est transformé en azote organique. Cette diminution de $N\text{-}NH_4^+$ (25% de NTK à 11% de NTK) et la consommation des nitrates lors du procédé permettent de penser que les chances de lessivage de l'ammoniac et des nitrates vers les cours d'eau lors de l'épandage agricole seront beaucoup réduites. Cette diminution d'ammoniac rend les boues moins odorantes. Globalement, la valeur fertilisante des boues n'est pas grandement modifiée.

L'étude de la filtration des boues traitées permet de conclure que celles-ci sont facile à déshydrater lorsqu'elles sont comparées aux boues anaérobies non traitées. Elles ne requièrent pas d'ajout de polymère floculant. Les technologies qui semblent les plus appropriées sont les filtres presses à plateaux et les centrifugeuses. La précipitation des métaux à pH=10 avec la chaux s'opère sans problème. Le volume du résidu métallique à gérer est 55 fois moindre que le volume des boues originales à 20% de solides totaux. En effet, pour 33 tonnes de boues digérées sèches produites (usine de la taille de celle de la CUQ), il y a 165 tonnes de boues (20% ST) à enfouir comparativement à 3 tonnes de résidu métalliques (50% ST). La balance des boues devenant acceptable pour l'épandage agricole.

Une usine de cette taille génère 43,9 t par jour de boues non digérées ce qui équivaut à environ 33 t/jr de boues digérées anaérobies. Le coût de la digestion selon l'EPA des États-Unis serait de 70 $ CAN/t brute, à cela il faut ajouter 38,44 $ CAN/t pour déshydrater les boues à 20%. Si le site est à 45 km, à 8 $ CAN/t humide, il en coûte 40 $ CAN/t sèche pour le transport au site en plus de 16,50$ CAN/t humide soit 82,50 $ CAN/t sèche pour l'enfouissement. Il en coûte en tout 230,94$ par tonne sèche digérée pour l'enfouissement sanitaire. La décontamination pour l'épandage agricole comporte les coûts suivants: 70 $ CAN/t pour la digestion anaérobie, 98,43 $ CAN/t pour la décontamination et la déshydradation environ 63 $ CAN/t pour l'épandage des boues à 30% ST. Pour un total de 231,43 $ CAN/t sèche gérée de cette façon. La coincinération des boues avec les déchets domestiques coûte pour sa part environ 300 $/t. De ces chiffres, il ressort que la décontamination et l'épandage agricole serait aussi économique que l'enfouissement sanitaire et moins dispendieux que la coincinération. L'épandage agricole représente un apport d'environ 60 $ CAN/t en engrais ce qui abaisse son coût réel pour la société à 171,43 $. C'est une option qui respecte les cycles naturels. Cette option évite de surcharger les sites d'enfouissement sanitaire qui comportent un risque de contamination des nappes phréatiques. Si le résidu métallique généré lors de la décontamination des boues ne peut être recyclé et qu'il se révèle être un déchet dangereux, il en coûterait de 10 à 15% de plus pour en disposer chez Stablex.

L'évaluation préliminaire des coûts place, donc, avantageusement l'option décontamination et épandage agricole face à l'enfouissement sanitaire et l'incinération. Ceci en plus des bénéfices à l'environnement que comporte cette option. Des essais à l'échelle pilote sont envisagés et les possibilités d'application du procédé à d'autres produits contaminés sont étudiées.

LES ORGANOCHLORES DANS LA CHAINE ALIMENTAIRE DE L'ARCTIQUE QUEBECOIS: Analyse de risque pour les populations inuit.

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De nombreux organochlorés sont transportés des régions industrialisées vers l'Arctique via l'atmosphère. Ils s'accumulent progressivement dans la chaîne alimentaire pour atteindre des niveaux élevés dans les tissus des poissons et surtout dans ceux des mammifères marins (phoques, bélugas, morses).

Cette faune aquatique est la base de l'alimentation des populations inuit du Nouveau-Québec. Ces deux éléments, environnemental et nutritionnel rendent donc ces populations particulièrement exposées aux organochlorés.

En 1988, nous avons recueilli et analysé 24 laits maternels de femmes inuit résidant dans les six villages de la Baie d'Hudson. Les données de comparaison étaient constituées de 48 laits de femmes résidant à Québec et Baie-Comeau.

Les analyses ont porté principalement sur les biphényles polychlorés (BPC) le dichlorodiphényl-dichloroéthylène (DDE) et les polychlorodibenzo-dioxines (PCDD) et polychlorodibenzo-furanes (PCDF).

Les concentrations de BPC et de DDE retrouvées dans le gras du lait étaient respectivement de 3.6 et 1.87 mg/kg chez les femmes inuit comparées à 0.77 et 0.57 mg/kg chez les femmes du sud de la province.

Cependant, les concentrations mesurées en PCDD et PCDF exprimées en toxicité équivalente à la 2,3,7,8 TCDD étaient de 24.7 ppt (ng/kg) soit légèrement supérieures à celles retrouvées dans les régions industrialisées.

Les impacts de cette contamination sur la population adulte et sur les enfants allaités seront discutés dans une perspective de risques-bénéfices.

APPROCHE ÉCOTOXICOLOGIQUE APPLIQUÉE A L'ÉVALUATION D'ABAT-POUSSIERES UTILISÉS SUR LES ROUTES DU QUÉBEC

par

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En Amérique, une bonne partie du réseau routier est constitué de routes non asphaltées donnant accès aux territoires agricoles et forestiers. Le passage de véhicules sur ces routes soulève des nuages de poussières qui engendrent des problèmes de sécurité routière et des nuisances.

Divers produits chimiques sont donc épandus chaque année sur ces routes afin d'y contrôler les poussières. Quoiqu'utilisés depuis de nombreuses années, plusieurs de ces abat-poussières n'ont jamais fait l'objet d'un examen exhaustif en regard de leur impact potentiel sur l'environnement.

Le gouvernement du Québec a donc mandaté le ministère de l'Environnement et le ministère des Transports afin de réaliser une étude conjointe sur les principaux produits utilisés au Québec soit: le chlorure de calcium, les lignosulfonates (calcium et ammonium) et une émulsion bitumineuse. La société Sodexen inc. ainsi que l'École Polytechnique ont également participé à la réalisation de cette étude.

L'approche écotoxicologique encadrant cette étude a permis d'estimer le pctentiel de contamination des différentes composantes de l'environnement (eau-air-sol) susceptibles d'être touchées par les pratiques habituelles d'épandage d'abat-poussières. La démarche séquentielle d'évaluation comprend trois blocs:

Caractérisation des produits:
- Composition, présence d'éléments toxiques
- Détermination des seuils de toxicité envers les biocénoses aquatiques (bioessais: Microtox, Selenastrum, Daphnia, Truite) et terrestres (germination orge/cresson, vers de terre)
- Vitesse de dégradation physico-chimique et de biodégradation en conditions contrôlées, produits de dégradation

Essais en modèles réduits:
- Profils reconstitués de sols en colonnes et en bacs pour évaluer, en conditions contrôlées, la mobilité des éléments constituant les abat-poussières

Essais sur routes expérimentales:
- Contamination de la chaussée, des sols environnants et persistance des produits
- Infiltration vers la nappe phréatique
- Lessivation vers les fossés et les eaux de surface
- Érosion éolienne par le passage des véhicules

L'identification et l'évaluation des risques découlant de l'utilisation de ces abat-poussières permettent de déterminer des pratiques sécuritaires d'épandage. Un protocole d'examen des nouveaux produits et la mise en place d'un programme de contrôle de qualité des abat-poussières déjà sur le marché complètent ces bonnes pratiques.

L'ENFOUISSEMENT SÉCURITAIRE DES DÉCHETS SPÉCIAUX ET DES SOLS CONTAMINÉS AU QUÉBEC

Ministère de l'Environnement du Québec

Ste-Foy, Québec

Serge Goulet

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AQUEOUS FOAM SCRUBBING
A MECHANISM TO MITIGATE ACCIDENTAL TOXIC GAS RELEASES

by

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Foam scrubbing is a procedure to cleanse contaminated air by entraining the air in aqueous foam. Once encapsulated within the foam, particulates, condensibles, and some gases are captured when they contact the bubble wall.

Foam scrubbing has been investigated extensively with excellent results in terms of scrubbing efficiency, particularly for water soluble materials and submicron particulates. Its failure to achieve widespread use as a continuous on-line system has been economic. High costs were foreseen to collapse the foam and recycle the solution; a must for a continuous operation.

The search for suitable mechanisms to control accidental toxic gas releases following the Bophal disaster effected a review of foam scrubbing. In this scenario, the foam system would be on standby, activated only in an emergency. There would be no need to recycle foam solutions.

Foam generator(s) could replace ventilating fans and act in that mode until needed. They would convert to foam generation in an emergency by simple actuation of the system controls.

Foam is collected in an enclosure. Foam drainage, including the entrapped contaminants, is collected for treatment and disposal.

Significant data has been derived on simple scrubbing of the air stream by standard foam solutions. As examples, ammonia concentrations in air can be reduced by 70% in less than 5 minutes. Likewise, chlorine can be reduced more than 65% in 8 minutes.

Scrubbing efficiency can be improved by incorporating reactants in the foam. Adding sulfuric acid to the foam solution improves the efficiency of ammonia removal, as does the addition of ammonia to the foam solution in the removal of chlorine.

Chlorine, due to its low solubility, requires materials other than the simple neutralizer, but 100% removal can be achieved.

By adding materials to the foam, even materials with very limited solubility such as sulfur dioxide, can be scrubbed with good efficiencies. Although this requires custom tailored foam chemistries, in most cases the toxic material to be scrubbed is known in advance, allowing such tailoring.

Particulate materials can also be scrubbed either alone or in combination with soluble gases. Test programs have been conducted with water soluble chlorides, such as $SiCl_4$, where the release is a mixture of HCl and SiO_2 particulates. Both phases are effectively removed with the elimination of the visible plume.

The U.S. Navy has successfully used foam scrubbing to remove Li_2O and LiOH from the air during large-scale testing of lithium fire extinguishants. The visible plume of lithium compounds was eliminated, but testing of the foam drainage showed it to be highly acid. This shows that the foam was also scrubbing the acid decomposition products of the halon materials in the test extinguishants.

HAZARDOUS WASTE EXPORTS: A GLOBAL POLICY FOR A SUSTAINABLE WORLD

by

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ABSTRACT

The increasing volume of toxic waste exports to developing countries over the past decade, and their uncontrolled disposal in countries without adequate waste management systems have caused serious environmental problems and international concern. This presentation is a summary of a larger study: "Toxic Waste Exports to the Third World: An Analysis of Policy Options and Recommendations for an International Protocol to Protect the Global Environment" conducted at the Massachusetts Institute of Technology (MIT). It examines national, regional and international policies, including the Basel Convention, to control transboundary movements of hazardous wastes and shows that the existing policies are insufficient. Concrete policy options and recommendations are developed to strengthen the Basel Convention, currently the sole international protocol regulating the export of toxic wastes.

The scope and scale of current waste export practice are developed by focusing on underlying technical, economic, and socio-political factors, identifying the main reasons for the export of toxic wastes:

- Increasing generation of hazardous wastes
- Limited disposal capacity in industrialized countries
- Large foreign debts as well as a general economic crisis in many developing and newly industrialized countries

Description of the problem will be followed by a discussion of existing policies, identifying their strengths and weaknesses, and examining their economic effectiveness, equity balance, sustainability and feasibility for implementation. The results of the analysis show that considerable improvements in existing policies are essential for better control of environmental damage from hazardous waste exports.

Finally, a set of specific recommendations addressing these problems will be presented.

L'ÉVALUATION DE L'EXPOSITION D'UNE POPULATION À UNE CONTAMINATION ENVIRONNEMENTALE PAR LE PLOMB.

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En 1989, on découvrait à St-Jean sur Richelieu qu'une usine de récupération de batterie en opération depuis 5 ans avait contaminé les sols d'un quartier résidentiel. Une enquête épidémiologique fut mise sur pied rapidement afin de déterminer l'ampleur de l'exposition au plomb des populations.

A la fin de l'été, des prélèvements sanguins furent effectués chez 510 enfants résidant dans le territoire contaminé. Dix sept enfants présentaient une plombémie $\geq$ 20 µg/dl. La contamination par le plomb était maximale chez les enfants âgés de 6 mois à 5 ans résidant à proximité de l'usine: moyenne géométrique des plombémies = 13.6 µg/dl (IC 95% = 11.1-16.5). L'exposition des enfants diminuait progressivement au fur et à mesure que l'on s'éloignait de la source de contamination pour devenir normale en périphérie de la zone étudiée: moyenne géométrique des plombémies des enfants âgés de 6 mois à 5 ans = 5.9 µg/dl (IC 95% : 5.4-6.5).

La présente étude, associée à la caractérisation environnementale entreprise par le ministère de l'environnement du Québec s'est révélée très utile pour la prise de décision quant à la décontamination des sols contaminés par le plomb.

Fourth Conference on Toxic Substances

April 4-5, 1990

POSTER ABSTRACT

The Application of GIS Technology to Toxic Substance, Resources at Risk Assessments

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The presence of toxic organic materials in the water, bottom sediments and biota of the Atlantic Region has attracted increasing concern. Most environmental contamination is either a direct result of, or enhanced by, anthropogenic activity. It was felt that land use data could be used to identify areas of potential pesticide and contaminant input, as the presence of certain factors in an area will increase the potential for higher levels of contaminants. By identifying the areas in which these factors are present, one may infer the existence of possibly higher toxic chemical loads. Previously, however, land activity information has not been readily accessible to water resource managers and investigators. The objectives of this study were to: identify and rank areas of potential anthropogenic sources of contaminants based on land use data, to verify the resultant potential areas by use of existing Water Quality Branch data, and to illustrate how such information could be used during the design of monitoring programs and in site priorization.

To accomplish these tasks relevant data sets were obtained from the Canada Land Data System of Environment Canada. The micro-computer based SPANS™ Geographic Information System was used to integrate land use information such as forestry use and capability, agricultural use and capability, and population density. Two principal hypothesis maps were generated based on land use data, industrial location and demographic data bases. The Potential Sources of Pesticides map illustrates the potential sources of agricultural pesticides while the Potential Sources of Toxics map illustrates the combination of agricultural, industrial and population factors. A relative scale was employed to rank regional contaminant potential on a "Low" to "Very High" basis. An areal analysis of the toxics map indicated that approximately 10 percent of the region fell into the two highest categories.

Water Quality Branch toxic chemical and LRTAP (Long Range Transport of Atmospheric Pollutants) program data confirmed the accuracy of this map. Where Branch data indicated elevated contaminant (PAH) concentrations, 78 percent of these observations

were in the two highest areas on the hypothesis map. Additionally, a strong correlation between the potential pesticide map and observed nutrient concentrations in LRTAP data supported the validity of the hypothesis maps.

The location of abandoned waste site data expanded the data base available and illustrated that GIS has application within the Canadian Environmental Protection Act (CEPA). The ability to formulate effective monitoring within CEPA will be one area of direct GIS application.

Such information can assist water resource managers to plan monioring projects, priorize site selection, and identify "hot spots". The ability to integrate various data bases opens up areas of investigation that were previously difficult. The inclusion of geological, hydrological and biological data, secondary industry, and atmospheric information, will facilitate greater ecosystem understanding, by allowing the modelling of various processes and inter-relationships. Future improvements in the availability and scale of the various data sets will enable refinements and expanded utility of the risk assessment approach as both a proactive and reactive environmental management tool.

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Dioxins and Furans: Health and Environmental Assessment Under CEPA

The Canadian Environmental Protection Act (CEPA), established in June of 1988, provides a systematic and comprehensive framework to control toxic substances.

The Priority Substances List established under CEPA identifies substances that are to be given priority for assessment of their potential to harm the environment or human health in Canada. The original list had 44 entries, including single substances, classes of substances, and effluents.

Substances that appear on the Priority Substances List must be assessed to determine whether they are "toxic" according to the definition in Section 11 of the Act, which states, in part:

> "...a substance is toxic if it is entering or may enter the environment in a quantity or concentration or under conditions
> (a) having or that may have an immediate or long-term harmful effect on the environment;
> (b) constituting or that may constitute a danger to the environment on which human life depends;
> (c) constituting or that may constitute a danger in Canada to human life or health."

The PSL has been further subdivided into three groups according to their priority for assessment. Group I includes dioxins and furans which are the first substances to be assessed under the Act.

Assessment of Dioxins and Furans

Dioxins and furans can enter the Canadian environment as complex mixtures from three major sources: production and use of some commercial chemicals, incineration, and pulp mills which use chlorine bleaching. Dioxins and furans have been found in all compartments of the ecosystem. All animals and humans in Canada are exposed to minute quantities of dioxins and furans.

2,3,7,8-tetrachlorodibenzodioxin (and to a lesser extent, the other 2,3,7,8-substituted dioxins and furans) are extremely toxic to test mammals, with a wide variation in sensitivity between species. Longer-term exposure to lesser amounts can affect reproduction, cause birth defects, damage the liver and suppress the immune system. Exposure to 2,3,7,8-tetrachlorodibenzodioxin and some other 2,3,7,8-substituted dioxins causes cancer in rodents; this effect is thought to be produced by an indirect mechanism, rather than by direct action on the genetic material.

Studies of human populations indicate that exposure to high doses of dioxins and furans as contaminants of other chemicals leads most often to a skin condition called chloracne. Some of the people affected have also displayed other adverse effects on the skin, liver, immune system, senses, or behaviour. Extreme exposures of women to furans in contaminated rice oil in Japan and Taiwan may have been responsible for reproductive anomalies and infant mortality; reproductive effects are equivocal in other high-exposure subpopulations. To date, there has been no adequate demonstration that human populations exposed to dioxins and furans have suffered excess cancer.

Based on the no-observed-adverse-effect-level for cancer and reproductive effects of 1 nanogram of 2,3,7,8-TCDD per kilogram of body weight per day from studies using rats, and a 100-fold uncertainty factor, it is concluded that human intakes should be below 10 picograms of 2,3,7,8-TCDD toxicity equivalents per kilogram of body weight per day averaged over a lifetime.

The average daily Canadian intake of dioxins and furans over a lifetime is estimated to be between 2.0 to 4.2 picograms of 2,3,7,8-TCDD toxicity equivalents per kilogram of body weight per day. Virtually all of this intake comes from food.

However, exposures for certain subgroups, such as species of wildlife and persons consuming large quantities of highly contaminated fish, can approach or exceed 10 picograms of 2,3,7,8-TCDD toxicity equivalents per kilogram of body weight per day. Elevated concentrations of these substances in some shellfish in the vicinity of some pulp mills that use chlorine bleaching have necessitated closure of the affected fisheries in order to protect human health. Adverse effects on reproduction in populations of fish-eating birds have been linked to high ambient exposures to dioxins and furans, or accompanying contaminants, in the Great Lakes and on Canada's West Coast.

While most chemical sources of dioxins and furans are already subject to controls, these substances continue to be released from pulp mills that employ chlorine bleaching and from incinerators.

The results of the assessment of the scientific data and the conclusions of the Task Force on dioxins and furans will be presented.

Utilisation d'une méthode de mesures environnementales dans l'évaluation des risques pour la santé: le cas de la population d'une école secondaire exposée à des poussires de plomb.

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Suite à la découverte de poussières de plomb dans les locaux de l'école, le Département de santé communautaire du CHUL a reçu en mai 1989 une demande pour évaluer cette problématique. L'évaluation devait porter principalement sur deux points:

1) Si ces poussières provenaient de la salle de tir située dans le sous-sol de l'école
2) Si l'exposition à ces poussières comportait des risques pour la santé de la population de l'école

L'analyse des échantillons, prélevés dans les locaux de l'école, a révélé la présence de plomb dans les poussières dont les concentrations variaient de 180 à 537 400 µg/g. La concentration la plus élevée était celle du local désaffecté de l'audiovisuel (537 400 µg/g). Ceci s'explique par le fait que la fenêtre de ce local est directement située au dessus de la sortie extérieure du ventilateur de la salle de tir. Si on exclue cet échantillon, la concentration de plomb la plus élevée était de 5 200 µg/g. On peut retrouver jusqu'à 2 800 µg/g de plomb dans les poussières déposées des maisons résidentielles.

Les conclusions de l'étude sont:

1) Que l'école présente un problème de contamination par des poussières de plomb.
2) Que les activités de la salle de tir sont la principale source de contamination.
3) Que cette contamination provient du rejet extérieur des poussières de plomb par le système de ventilation de la salle de tir.
4) Qu'il est possible d'ingérer ces poussières par le contact buccal avec des mains contaminées.
5) Que l'absorption est principalement digestive et surtout importante chez les jeunes enfants.
6) Que les risques pour la santé humaine sont minimes pour la population générale du pavillon.
7) Que seul le local désaffecté de l'audiovisuel représente un risque potentiel d'intoxication au plomb, à condition d'y effectuer des travaux ménagers pendant plusieurs jours consécutifs.

En conséquence, le Département de Santé communautaire du CHUL est d'avis que la fermeture de la salle de tir est la meilleure décision à prendre afin d'éliminer une source additionnelle d'exposition au plomb et d'assurer une protection maximale pour la santé de la population de cette étude secondaire.

L'ENTREPOSAGE DE BOIS TRAITÉ A HYDRO-QUÉBEC

par:

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Hydro-Québec est un des principaux utilisateurs au Québec de poteaux de bois traité avec d'autres entreprises reliées principalement au domaine des communications. Le réseau de distribution d'Hydro-Québec comprend au-delà de 1,5 millions de poteaux. Chaque année, pour des raisons d'entretien, de réparation ou de prolongement de son réseau, Hydro-Québec achète plus de 80,000 poteaux qu'elle entrepose dans plus de 90 sites permanents répartis dans ses régions administratives.

Dans une proportion de 95%, ces poteaux sont traités au pentachlorophénol (PCP) Depuis quelques années, au Canada comme partout ailleurs dans le monde, l'utilisation des pesticides soulève des oppositions sur les plans de l'environnement et de la santé. En 1979, Agriculture Canada indiquait déjà son intention de limiter l'utilisation du PCP dans son usage comme préservatif du bois.

Dans ce contexte, la vice-présidence Environnement d'Hydro-Québec élaborait un programme d'études concernant les préservatifs du bois et plus particulièrement le PCP. Ce programme vise à couvrir tous les aspects de la gestion du bois traité: achat, entreposage, utilisation, comportement dans l'environnement, disposition, décontamination des sols et traitement de l'eau contaminée. L'étude sur l'entreposage du bois nous est apparue comme prioritaire compte-tenu du nombre de sites et de la concentration des poteaux en ces lieux.

L'étude en question a été réalisée par une équipe de spécialistes d'Envirobec et supervisée par trois conseillers en gestion des contaminants de la vice-présidence Environnement d'Hydro-Québec.

Cette étude repose principalement sur l'évaluation de la sensibilité du milieu et de la vulnérabilité des terrains où se trouvent les différents sites d'entreposage ainsi que sur le dépistage du préservatif dans les différentes matrices susceptibles d'être affectées, soit l'eau, l'air et le sol.

Dans un premier temps, le rapport collige les données de la littérature en relation avec les problèmes associés aux cours d'entreposage de bois traité. C'est ainsi qu'on expose les risques reliés aux différentes formes que peut prendre le PCP en fonction du pH. Sous sa forme ionisée, le produit devient plus soluble et donc, plus mobile alors que sa volatilité ainsi que sa capacité d'être adsorbé diminuent sensiblement.

Dans un second temps, il expose l'inventaire actualisé de l'ensemble des cours d'entreposage. Chaque site est alors catégorisé selon des critères reliés à sa localisation dans le milieu ainsi qu'à l'importance de la quantité de pièces de bois traité.

Les cours ont donc été classées en neuf catégories distinctes selon leur contenu en pièces de bois traité (petite moyenne ou grande) et selon le milieu où elles sont localisées (urbain, périphérique ou agricole).

Par la suite, nous avons choisi neuf sites représentatifs de l'ensemble des catégories afin de procéder à une caractérisation plus détaillée. Des analyses de sol, d'eau et d'air ont permis de mieux saisir l'importance de l'impact et orienter les mesures de correction.

Les résultats d'analyse montrent une concentration notable en PCP ainsi qu'en huiles et graisses en surface du sol mais déjà à une profondeur de 50 cm. les teneurs chutent de façon drastique. L'analyse des échantillons d'eau prélevés dans les fossés périphériques a montré une faible contamination par le PCP. En ce qui concerne les huiles et graisses cependant, la contamination était plus importante. Quant à la contamination de l'air, les résultats sont peu probants. La méthode à l'olfactomètre dynamique utilisée alors s'est avérée inappropriée pour les faibles concentrations en présence.

Suite à la synthèse des problèmes relevés lors de la caractérisation, l'étude propose enfin, à l'aide d'un schéma décisionnel, une démarche globale incluant des criteres environnementaux pour la localisation des cours d'entreposage ainsi que des modes d'aménagement pour les sites existants ou futurs ne rencontrant pas tous les critères de localisation.

Ces critères de localisation prennent en considération la texture ainsi que la perméabilité du sol, le relief, la profondeur du roc et de la nappe d'eau souterraine et, enfin, la proximité de plans d'eau.

Les objectifs des modes d'aménagement sont d'empêcher le cheminement du contaminant dans l'environnement et d'éviter la contamination des sols dans l'aire d'entreposage.

Dans les modes d'aménagement proposés, l'étude distingue les modes mineurs et majeurs. Les modes d'aménagement mineurs sont des mesures facilement applicables à titre de mesures correctives. Nous mentionnerons les quelques mesures suivantes pour permettre de préciser l'ampleur des tels modes :

- utilisation de supports pour tous les empilements;
- réduction des surfaces d'entreposage;
- système de diversion d'eau de ruissellement;
- utilisation de matériaux absorbants sous les empilements.

Les modes d'aménagement majeurs proposés impliquent quant à eux la construction d'infrastructures qui engendrent des coûts non négligeables et un encombrement important qui demandera des modifications et des ajustements dans les pratiques des utilisateurs.

Malgré l'application des critères de localisationet des modes d'aménagement, un contrôle de qualité sévère des arrivages de poteaux demeure primordial. Chacune des cours d'entreposage devra faire l'objet d'une évaluation à partir de la grille d'analyse développée dans l'étude afin de prioriser les interventions. De nouvelles études seront entreprises concernant les problèmes d'odeur liés à l'activité d'entreposage ainsi que la faisabilité technico-économique des aménagements proposés.

MEASUREMENT OF POTENTIALLY TOXIC AIRBORNE CONTAMINANTS in CANADIAN URBAN AIR

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The River Road Environmental Technology Centre (RRETC) of Environment Canada has undertaken numerous projects to develop improved measurement techniques for air pollutants identified as high priority because of their toxic nature and because of the potential for significant population exposures. Developed methods have been phased into urban monitoring networks allowing the establishment of a substantial Canadian data base on toxic air pollutants.

This paper will present a description of Environment Canada's sampling and analytical methodologies for toxic air pollutants and will summarize measurement results for a number of important compounds.

The pollutants for which methods have been developed can be divided into three major categories: semi-volatile organics (organic compounds with both a particulate and vapor phase in ambient air), volatile organics and inorganic inhalable particulate matter and associated metals. *Table 1* contains a summary of important categories and sub-categories of toxic air pollutants. An overview of Environment Canada's monitoring protocols is contained in *Table 2*; included in the table are typical sample volumes and target detection levels.

A summary of the Canadian cities in which toxics monitoring is carried out is given in *Table 3*.

TABLE 1: IMPORTANT CATEGORIES OF TOXIC AIR POLLUTANTS

CATEGORY	SUB-CATEGORIES
Volatile Organics	Aromatics Alkyl Halides Chlorinated Aromatics Aldehydes & Ketones
Semi-Volatiles	Polycyclic Aromatic Hydrocarbons (PAH) Polychlorinated Biphenyls (PCB) Chlorophenols (CP) Chlorobenzenes (CB) Polychlorinated Dibenzo-p-Dioxins (PCDD) Polychlorinated Dibenzofurans (PCDF)
Inorganics	Inorganic Compounds Sulphates Nitrates

TABLE 2: ENVIRONMENT CANADA AMBIENT MONITORING PROTOCOLS

Compound	No. of Species or Isomer Groups Measured	Sampling Method*	Analytical Method*	Sample Volume (24 h)	Target Dection Level
PCDD / PCDF	10	Hi-Vol/PUF	GC-LRMS	1000 m^3	0.05 pg/m^3
Polychlorinated Biphenyls (PCB)	10	Hi-Vol/PUF-XAD	GC-MSD	500 m^3	0.05 ng/m^3
Chlorinated Benzenes (CB)	4	Hi-Vol/PUF-XAD	GC-MSD	500 m^3	0.02 ng/m^3
Chlorinated Phenols (CP)	4	Hi-Vol/PUF-XAD	GC-MSD	500 m^3	0.06 ng/m^3
Polycyclic Aromatic Hydrocarbons (PAH)	25	Hi-Vol/PUF	GC-MSD	1000 m^3	0.02 ng/m^3
Inorganic Particulates (Part)	42	Dichotomous Sampler	EDXRF & IC	24 m^3	1- 50 ng/m^3
Volatile Organics (VOC)	90	Evacuated Canister	GC-FID/MSD	16 L	0.1 $\mu g/m^3$

* Abbreviations explained in the text.

TABLE 3: SUMMARY OF AIR TOXICS MONITORING LOCATIONS IN CANADA

City	Parameters Measured				
	VOC	Part.	PAH	PCB/CB /CP	PCDD/ PCDF
Halifax	☒	☒			
Quebec City		☒			
Arvida			☒		
Montreal	☒	☒	☒		
Ottawa	☒	☒			
Toronto	☒	☒	☒		
Hamilton	☒		☒		
Sarnia	☒				
Windsor	☒	☒	☒	☒	☒
Winnipeg	☒	☒			
Edmonton		☒			
Calgary		☒			
Vancouver	☒	☒			
Victoria		☒			

COLLOQUE sur les SUBSTANCES TOXIQUES

Montréal, 4-5 avril 1990
Séance IV: "NIMBY..."

Présentation
par Serge Cabana

-Conseiller principal en Communications
Hydro-Québec / siège social

-Président Communications
CUBPC

RÉSUMÉ

SYNDROME "NIMBY": DU PROBLÈME DE COMMUNICATIONS AU BESOIN DE CONCERTATION

THÈSE: Le phénomène de la résistance sociale à l'implantation de projets qui affectent l'environnement posera de plus en plus de problèmes aux développeurs, industries et gouvernements inclus.

COMMUNICATIONS: À la base, il y a un problème de communication entre promoteurs et populations touchées. Un dialogue de sourds s'installe entre partisans du développement et protecteurs de l'environnement. Les uns s'adressant à la raison, les autres à l'émotion. Avant tout, il faut une longueur d'ondes commune.

CONCERTATION: Pour surmonter le syndrome "Pas dans ma cour", il faut transformer le processus décisionnel lui-même. Les promoteurs doivent commencer en invitant les opposants à leurs projets à venir jouer dans leur cour, dès le début du processus. Car "hors de la concertation, point de solution".

CONCLUSION: Le dossier des BPC offre une occasion concrète et symbolique de démontrer qu'en travaillant ensemble, gouvernements, industries et groupes d'intérêts permettront à la société de régler ses problèmes d'environnements.

PLANIFICATION DE L'IMPLANTATION DU PROGRAMME DE REDUCTION DES REJETS INDUSTRIELS

Ministère de l'Environnement du Québec

Ste-Foy, Québec

M. Guy Demers

OBJECTIF

D'ICI 10 ANS, RÉDUIRE DE 75% L'ENSEMBLE DES REJETS INDUSTRIELS DANS L'EAU, L'AIR ET LE SOL, EN ACCORDANT UNE ATTENTION PARTICULIÈRE AUX REJETS TOXIQUES

PROBLÉMATIQUE

- ☐ POLLUANTS CONVENTIONNELS:
  L'IMPORTANCE DU VOLUME
  DES REJETS

- ☐ LES REJETS TOXIQUES

- ☐ LA MENACE À LA SANTÉ HUMAINE:
  - . EAU
  - . AIR
  - . SOL
  - . CHAÎNE ALIMENTAIRE

- ☐ DÉTÉRIORATION DE L'ENVIRONNEMENT

- ☐ 5% DES INDUSTRIES:
  80% DES REJETS

APPROCHE

- ☐ CIBLES PRIORITAIRES
- ☐ RENFORCEMENT RÉGLEMENTAIRE
- ☐ INTÉGRATION EAU - AIR - SOL
- ☐ CONCERTATION DES INTERVENANTS
- ☐ INCITATION (RECHERCHE ET DÉVELOPPEMENT)

LES CIBLES PRIORITAIRES

☐ LES INDUSTRIES LES PLUS SUSCEPTIBLES DE POLLUER (EAU - AIR - SOL)

589 —┬— 221 À COURT TERME
     └— 368 À MOYEN TERME

LES ÉTABLISSEMENTS SOUMIS À UNE ACTION PRIORITAIRE

SECTEURS INDUSTRIELS	À COURT TERME	À MOYEN TERME
. PÂTES ET PAPIERS	60	
. MINES	60	50
. MÉTALLURGIE	27	34
. CHIMIE	71	88
. PÉTROLE	3	--
. REVÊTEMENT DE SURFACE	--	196
TOTAL:	221	368

RÈGLEMENTS EXISTANTS

☐ LOI DE LA QUALITÉ DE L'ENVIRONNEMENT

☐ 7 RÈGLEMENTS:

EAU
- PÂTES ET PAPIERS
- RAFFINERIES DE PÉTROLE

AIR
- QUALITÉ DE L'ATMOSPHÈRE
- BÉTONS BITUMINEUX
- CARRIÈRES + SABLIÈRES

SOL
- DÉCHETS DANGEREUX
- DÉCHETS SOLIDES

MOYENS

RENFORCEMENT RÉGLEMENTAIRE

☐ MODIFICATIONS AUX RÈGLEMENTS EXISTANTS

☐ NOUVEAUX RÈGLEMENTS:

- ATTESTATION D'ASSAINISSEMENT
- REJETS DANS LES ÉGOÛTS
- REJETS DES STATIONS MUNICIPALES

MOYENS

INCITATION

☐ RECHERCHE ET DÉVELOPPEMENT SUR LES TECHNOLOGIES PROPRES

TECHNOLOGIES DE RÉDUCTION

FIXATION DE NORMES BASÉES SUR:

☐ BCT (MTC)

☐ BATEA (MTDER)

☐ NSPS (MTNS)

☐ MESURES INTERNES (4-R)

L'ATTESTATION D'ASSAINISSEMENT

SON ORIGINE

ÉTATS-UNIS

☐	WATER POLLUTION CONTROL ACT	- 1972
☐	CLEAN WATER ACT	- 1977
☐	L'AGENCE E.P.A. DÉLÈGUE À 39 ÉTATS AMÉRICAINS L'AUTORITÉ D'ÉMETTRE LES PERMIS FÉDÉRAUX	- 1973 À 1977

SA NATURE

PAS UNE CARTE BLANCHE POUR POLLUER

UNE AUTORISATION À DÉVERSER DES POLLUANTS:

- LÉGALEMENT
- EN QUANTITÉS CONTRÔLÉES
- POUR UN TEMPS LIMITÉ
- AVEC UN ÉCHÉANCIER DÉTERMINÉ

SON CONTENU

- ☐ ANALYSE PRÉALABLE DES REJETS
- ☐ NORMES DE REJETS
- ☐ SURVEILLANCE PÉRIODIQUE DES REJETS
- ☐ ÉCHÉANCIER DE CONFORMITÉ
- ☐ ÉTUDES PARTICULIÈRES

SES AVANTAGES

- ☐ OBLIGE UNE RENCONTRE PÉRIODIQUE AVEC L'INDUSTRIE
- ☐ INTÈGRE L'ENSEMBLE DES EXIGENCES DANS UN MÊME DOCUMENT LÉGAL
- ☐ PARTICULARISE LES EXIGENCES POUR CHAQUE ENTREPRISE
- ☐ CENTRE SUR LES RÉSULTATS ET NON SUR LES MOYENS
- ☐ CONCRÉTISE L'APPROCHE INTÉGRÉE (EAU - AIR - SOL)
- ☐ CONTRÔLE PLUS ÉTROITEMENT LES REJETS
- ☐ RESPONSABILISE DAVANTAGE L'ENTREPRISE

SON COÛT

☐ FRAIS ADMINISTRATIFS ANNUELS

- CHARGE ADMINISTRATIVE DU MINISTÈRE
  (5,000 $ PAR ENTREPRISE)

- FRAIS SELON L'IMPORTANCE DES REJETS

PARI
ÉTAPES FRANCHIES

. JUIN 1988:	- CONSULTATION PUBLIQUE
. DÉCEMBRE 1988:	- SYNTHÈSE DES MÉMOIRES - VERSION MODIFIÉE DU PROGRAMME
. FÉVRIER 1989:	- LOI 99
. SEPTEMBRE 1989:	- PRÉPUBLICATION DU RÈGLEMENT . DÉCISION SUR LES COMITÉS TECHNIQUES

LA MISE EN OEUVRE DU PROGRAMME

- DÉBUT 1990:
  - ADOPTION DU RÈGLEMENT
  - PROMULGATION DES DÉCRETS
    - MISE EN VIGUEUR SECTION IV.2 DE LA LOI
    - DÉSIGNATION DES CATÉGORIES D'ÉTABLISSEMENTS VISÉES
    - CONSTITUTION DES COMITÉS TECHNIQUES

- JANVIER À JUILLET 1990:
  - RÉCEPTION DES DEMANDES D'ATTESTATION

LA LOI 99

(Modification de la Loi sur la
qualité de l'environnement)

1. ATTESTATION D'ASSAINISSEMENT (SECTION IV.2)

- . POUVOIRS DU MINISTRE
- . CONTENU DE L'ATTESTATION
- . OBLIGATIONS DU TITULAIRE
- . PROCÉDURES RELATIVES À LA DEMANDE ET À LA DÉLIVRANCE
- . MODIFICATION DE L'ATTESTATION

2. AMENDES

- . AUGMENTATION DU MONTANT
- . RESPONSABILITÉ DES ADMINISTRATEURS
- . POUVOIRS ACCRUS DES INSPECTEURS ET ENQUÊTEURS

3. OUVRAGES MUNICIPAUX D'ASSAINISSEMENT

RÈGLEMENT SUR L'ATTESTATION D'ASSAINISSEMENT

- LA CLÉ DE LA MISE EN VIGUEUR DE LA LOI 99

- SON CONTENU:
  - LE CONTENU DE LA DEMANDE
  - LA CONSULTATION PUBLIQUE
  - LES RÉGISTRES ET RAPPORTS
  - LES SANCTIONS
  - LA TARIFICATION

COMITÉS TECHNIQUES

- OUTIL DE CONCERTATION

- COMPOSITION

- MODE DE NOMINATION

- FONCTIONNEMENT